2002 Update of Water-Level Monitoring and Water-Quality Sampling
Butte Underground Mines and Berkeley Pit
Butte, Montana

1982 – 2002

1957 Photo of Berkeley Pit, MBMG Archives

prepared for

The Montana Department of Environmental Quality
Remediation Division
and
U.S. Environmental Protection Agency
Region VIII

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TABLE OF CONTENTS

List of Figures

List of Tables

Tables Page

Executive Summary

The Record of Decision and Consent Decree for the Butte Mine Flooding Operable Unit stipulates that a yearly update of data collected from the Post Remedial Investigation/Feasibility Study monitoring program be prepared. The report is to incorporate the most recent year's data with the existing data. This report presents data collected during the year 2002, combined with data collected since 1982, when ARCO suspended underground mine dewatering and mining in the Berkeley Pit.

Major new observations and developments discussed in this report are:

1. Changes in responsibility for monitoring activities and monitoring sites as a result of the 2002 Consent Decree.

2. Preconstruction activities related to the Horseshoe Bend water treatment plant and their influence on Horseshoe Bend Drainage flow monitoring. Site preparation for the water treatment plant and its associated facilities resulted in changes to the existing drainage channel, which required the relocation of the monitoring site, and temporary interruption of monitoring.

3. Inflow of water from the Horseshoe Bend Drainage into the Berkeley Pit continued. This inflow continued the increased rate of rise of water levels in the Berkeley Pit and associated underground mines.

4. West Camp pumping activities continue to maintain the ground-water level below the 5,435-foot elevation, stipulated in the 1994 Record of Decision. The volume of water pumped in 2002 was down about 5 percent from 2001 (247 vs. 260 acre-feet). With less water pumped during 2002, the water level rose over 1.25 feet throughout the system.

5. The annual Berkeley Pit model update resulted in a thirteen month change in the projected date (time-line) when the 5,410-foot water-level elevation would be reached at the Anselmo Mine. Water levels were predicted to reach this elevation in 2018, thirteen months sooner than shown in the 2001 model. The addition of Horseshoe Bend Drainage water, disposal of sludge from the Horseshoe Bend water treatment plant, and additional storm water flow from the Butte Hill into the pit were considered in the model update.

6. A special discussion of water-quality trends in the Travona Mine over the course of time is included with this year's report.

Water-level and water-quality data are presented in the same order and manner as the previous reports (MBMG Open-File Reports No. 376, No. 410, No. 435, No. 456, and No.473) for the reader's convenience. Hydrographs for <u>selected</u> sites and total and yearly water-level changes for all sites are presented. Water-quality data follow the presentation of water-level data in each section where water-quality data are available, as not all sites were sampled.

The U.S. Environmental Protection Agency and Montana Department of Environmental Quality began settlement negotiations with BP/Atlantic Richfield Company and the Montana Resources Group during the fall of 2001, reaching an agreement (Consent Decree) in March 2002. The US District Court approved and signed the Consent Decree August 2002. The Consent Decree provided for (among other things): 1) reimbursement of past EPA and DEQ costs associated with the Butte Mine Flooding Operable Unit; 2) funding for long-term water-level and water-quality monitoring of ground water and surface water; 3) long-term funding for public education program; 4) installation of four alluvial monitoring wells; and 5) construction, operation and maintenance of a two-stage, high-density, lime precipitation water treatment plant. The plant will have the capacity to treat up to 7 million gallons of water daily. The plant will initially treat water from the Horseshoe Bend Drainage and then ultimately from the Berkeley Pit as well. The cost of the plant design, construction, operation, and maintenance will be borne by the settling defendants (British Petroleum/Atlantic Richfield Company and the Montana Resources Group).

(The Consent Decree contains many more items than those listed above and the reader is referred to it for additional information.)

Acknowledgments

The information contained in this report represents the work of many companies and agencies over the past 21 years. Without their cooperation, this report could not have been prepared. Numerous individuals have been responsible for actual data collection. Their dedication and creativity in monitoring and sampling of mine waters provided the information that all future work and evaluations relied upon. The continued cooperation of Montana Resources and their contractor, ESE, and British Petroleum/Atlantic Richfield Company , is greatly appreciated.

Representatives of New Butte Mining and Montana Mining Properties continue to allow access to their properties for monitoring purposes. Special acknowledgment is given to the citizens of Butte who allow access to their private wells for monitoring purposes.

Special recognition is given to Mike Kerschen and James Rose, MBMG, for their dedication to monitoring and sampling tasks, and to Linda Albright, MBMG, for assisting with the preparation of this report.

The State of Montana, Department of Environmental Quality and the U.S. Environmental Protection Agency have provided funding for the MBMG to conduct monitoring and sampling activities and preserve continuity between various studies. This support has been invaluable; their realization that flexibility is needed in the monitoring program has allowed changes in monitoring as conditions change.

Errors and omissions remain the authors' responsibility.

List of Acronyms used in text

EPA	U.S. Environmental Protection Agency
DEQ	Montana Department of Environmental Quality
NWQL	U.S. Geological Survey National Water Quality Laboratory, Denver, CO
RPD	relative percent difference
USDA-Forest Service	U.S. Department of Agriculture - Forest Service
USGS	U.S. Geological Survey
ROD	Record of Decision
CD	Consent Decree
MBMG	Montana Bureau of Mines and Geology
BMFOU	Butte Mine Flooding Operable Unit
RI/FS	Remedial Investigation/Feasibility Study
BP/ARCO	British Petroleum/Atlantic Richfield Company
MR	Montana Resources
HSB	Horseshoe Bend
MCL	Maximum Contaminant Level
SMCL	Secondary Maximum Contaminant Level
CWL	Critical Water Level

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1982 – 2002

SECTION 1.0 SITE BACKGROUND

The Anaconda Company announced on April 23, 1982, that they were no longer going to operate their underground mine pump system, thus allowing the Butte underground mines and ultimately the Berkeley Pit to begin filling with water. The Anaconda Company established a centralized pump station, first at the High Ore Mine (figure 1-1) and later at the Kelley Mine (figure 1-2), where up to 5,000 gallons of water per minute was pumped from the underground workings to the surface. The centralized pumping of underground mine water began in the early 1900's. As the mine workings went deeper, the pump stations were relocated to deeper levels also. The water, which was acidic and contained substantial concentrations of copper and other trace metals, was used in the leach pad and precipitation plant operations. Allowing water in the underground mines to rise resulted in a corresponding rise in water levels in the bedrock adjacent to the mines. The Berkeley Pit also started to fill with metal-laden water.

The full nature of the influence that historic mine dewatering had on the local ground-water system was not well documented, thus a comprehensive water-level and water-quality monitoring network was established. Concerns about the site's long-term environmental impact on ground water and surface water led to the site being listed on the Federal EPA Superfund list. Current monitoring is the result of this listing.

The Butte Mine Flooding Operable Unit (BMFOU) Remedial Investigation/Feasability Study (RI/FS) began in 1990 and resulted in the 1994 Record of Decision (ROD) (EPA, 1994). The ROD included provisions for: 1) continued monitoring and sampling of both ground water and surface water, 2) diversion of the Horseshoe Bend Drainage (HSB) water away form the Berkeley Pit (to slow the pit filling rate), 3) incorporation of the HSB water in the Montana Resources (MR) mining operations for treatment, 4) construction of a water treatment plant if changes in mining operations (e.g. mine shutdown) prevent treatment of HSB water, and 5) establishment of a maximum level to which water in the underground mines and Berkeley Pit can rise, before a water treatment plant must be built and in operation.

The U.S. Environmental Protection Agency (EPA) and Montana Department of Environmental Quality (DEQ) began Consent Decree (CD) negotiations with BP/Atlantic Richfield Company and the

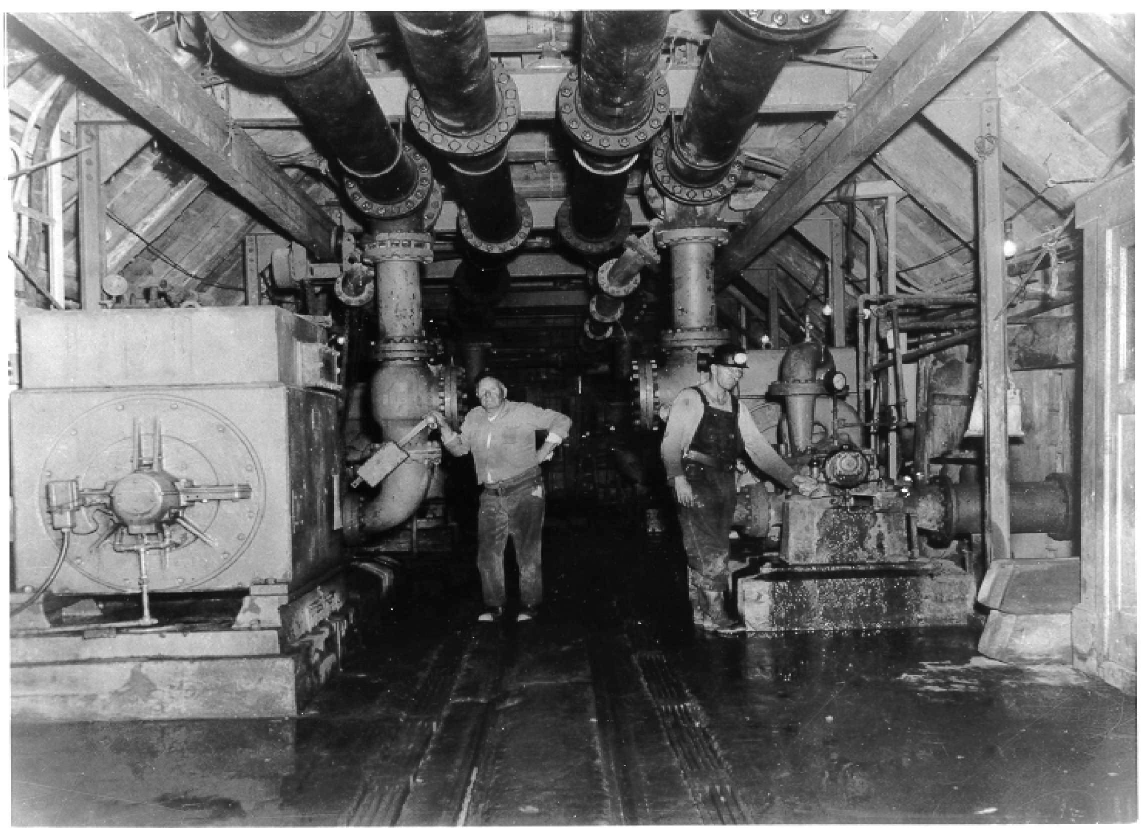


Figure 1-1. High Ore Mine 2800-level (top) and 3900-level (bottom) pump stations. (Photos courtesy World Museum of Mining.)

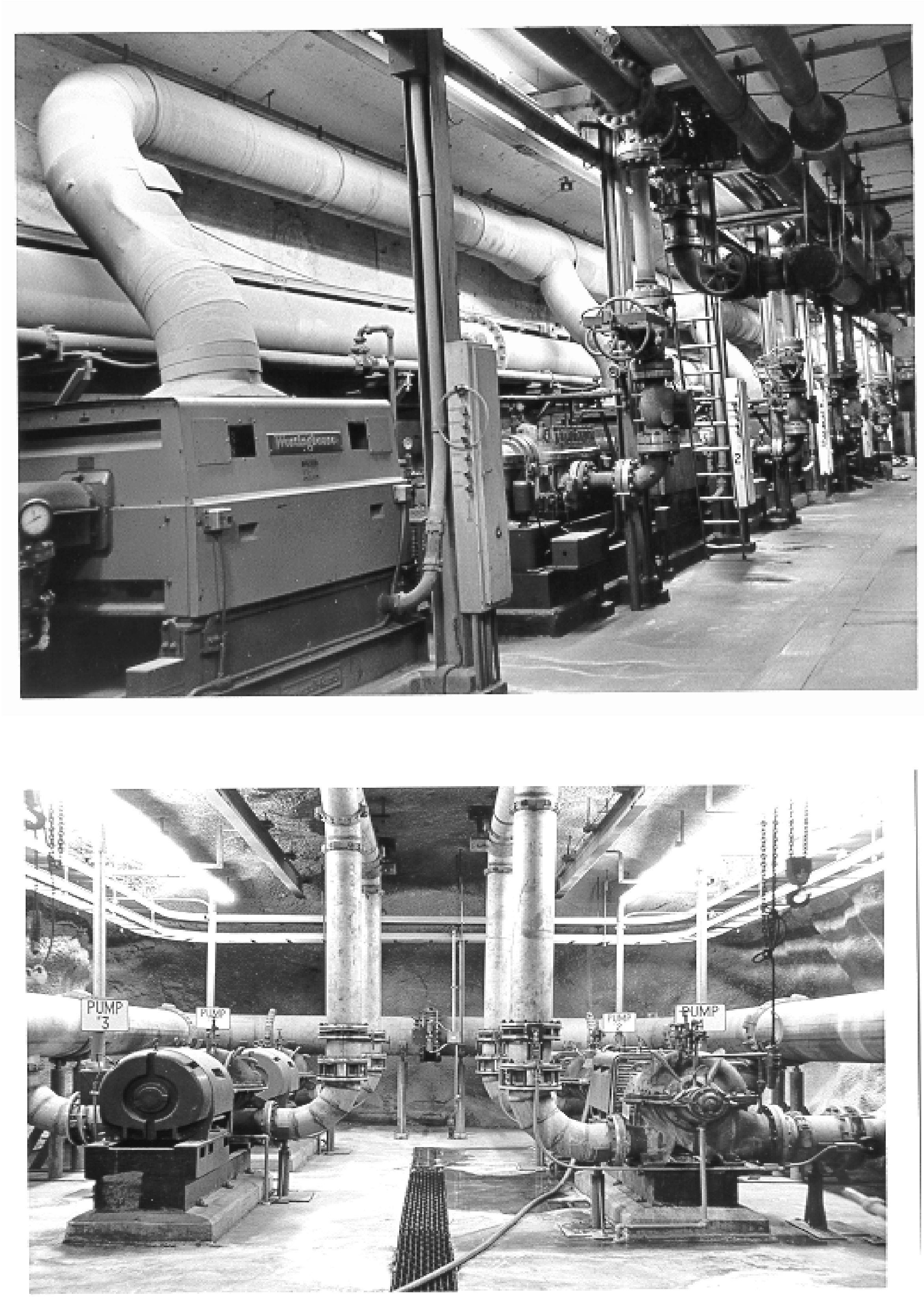


Figure 1-2. Kelley Mine, 3900-level pump station. (Photos courtesy World Museum of Mining.)

Montana Resources Group in the fall of 2001 and reached a tentative agreement in March 2002. The U.S. District Court approved the CD August 2002. The CD addressed all the current and future activities relating to the BMFOU and reimbursed EPA and DEQ for past costs associated with the site. Funding for the continuation of the long-term ground-water, surface-water, and Berkeley Pit/ Continental Pit monitoring were included in the CD. The monitoring is to be performed by the Montana Bureau of Mines and Geology (MBMG) under the direction of DEQ and EPA. BP/Atlantic Richfield Company and the Montana Resources Group agreed in the CD to be responsible for all costs associated with the design, construction, operation, and maintenance of a water-treatment plant for treating HSB, Berkeley Pit, and other contaminated waters associated with the site. Construction of treatment facilities will follow the time-line specified in the ROD. (Refer to the CD and the Explanation of Significant Differences, to see the entire scope of activities addressed in the CD and an explanation of differences from items contained in the 1994 ROD.)

Section 1.01 Introduction

The BMFOU 1994 ROD and subsequent 2002 CD specify that an annual review of water levels and water quality shall be performed. The first water-level review was completed in 1998 as a 15-year evaluation, from the beginning of flooding of the Butte underground mines and Berkeley Pit in 1982 through 1997 (Duaime, 1998); the present study is the fifth such report. Notable changes and a comparison of trends are discussed.

This report does not present an overview of the history of mining on the Butte Hill, nor the Superfund processes that have followed since the EPA designated the flooding underground Butte Mines and Berkeley Pit a Superfund site in 1987.

The reader is referred to the Butte Mine Flooding RI/FS, Butte Mine Flooding ROD, Butte Mine Flooding CD, and MBMG Open-File Report No. 376 for greater detail and information about the site.

Monitoring activities continued in 2002 in the East Camp, West Camp and Outer Camp systems (figure 1-3). The East Camp System includes mines and mine workings draining to the Kelley Mine pump station when mining and dewatering were suspended in 1982. The West Camp System includes workings that historically drained to the East Camp from the southwest portion of the Butte mining district, but were hydraulically isolated by the placement of bulkheads in interconnected mine workings to separate the West Camp from the East Camp. The Outer Camp System consists of the western and northern extent of mine workings that were interconnected to the East Camp at some time, but have been isolated with water levels returning to, or near pre-mining conditions. More than 85 percent of the underground mine workings had been inundated with water through 2002. By the time water levels

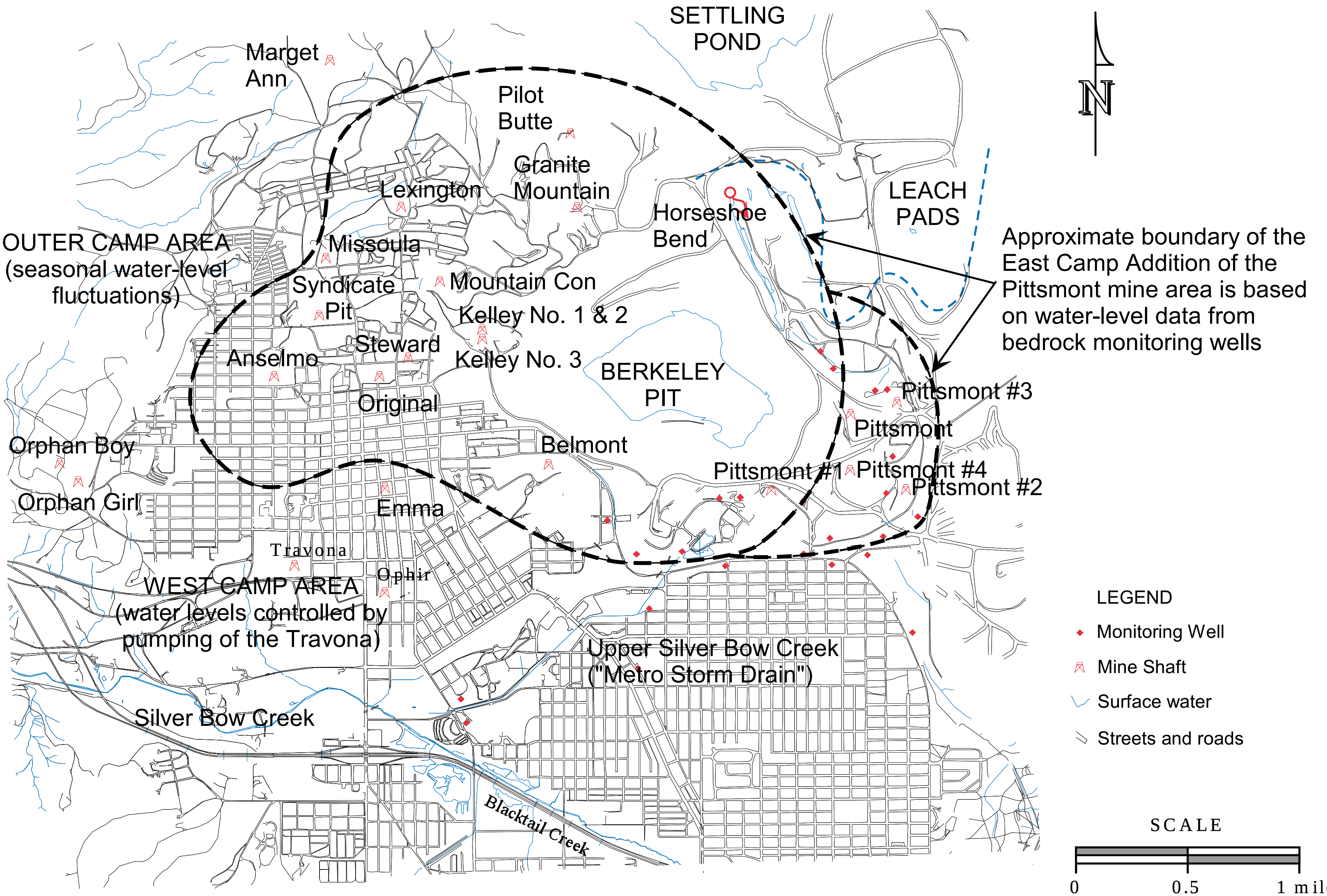


Figure 1-3. The mines of the Butte hill are presently considered in three groups: the East Camp, which includes the Berkeley Pit and the area east; the West Camp in the southwest part of the hill; and the Outer Camp which includes the outlying mines.

in the underground mines reached the elevation of the bottom of the Berkeley Pit, more than 66 percent of the workings had already been flooded.

Section 1.1 Notable 2002 Water-Level and Water-Quality Changes and Monitoring Activities

(1) Montana Resources' (MR) June 30, 2000, suspension of mining and milling operations continued throughout 2002. As a result, water from the HSB discharged into the Berkeley Pit. This additional input of water into the pit resulted in groundwater level increases in the surrounding bedrock. The average monthly rate of rise for 2002 was slightly more than 1.1 foot. The input of HSB water resulted in an additional 800 million gallons of water entering the East Camp system during 2002.

(2) Preconstruction activities related to the HSB water-treatment plant influenced HSB drainage flow monitoring. The weir installed in 2001 was relocated upstream at the outfall of what was called Pond 4, in MR's precipitation plant operation. Flow monitoring was interrupted off and on for several months while construction activities took place.

(3) The water level in the Continental Pit continued to rise as a result of MR's mining suspension. The only water pumped from the Continental Pit was during the summer and was used for dust mitigation during reclamation and preconstruction activities.

(4) Monthly water-quality samples were collected from the Continental Pit and HSB drainage.

(5) The November 2002 Alaskan earthquake had a short-term, limited affect on a number of East Camp bedrock water levels. A slight decrease in water levels occurred immediately after the earthquake. Water-level changes were influenced for periods of several hours to several months.

Section 1.2 Precipitation Trends

Precipitation during 2002 continued to be less than average. Total precipitation was 10.29 inches compared to the long-term average of 12.79 inches. This is a deficiency of 20 percent and is the fourth consecutive year of below-average moisture. Table 1.2.1 contains monthly precipitation totals from 1982 through 2002, while figure 1-4 shows this information graphically in comparison to the long-term yearly average. Overall precipitation totals, since flooding of the mines began, are very similar to the long-term average (12.84 inches vs. 12.79 inches). Figure 1-5 shows departure from normal precipitation from 1895 through 2002.

Table 1.2.1 Butte NOAA Precipitation Statistics, 1982-2002

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL AVERAGE
Mean	0.51	0.46	0.85	0.98	1.86	2.22	1.57	1.32	1.00	0.74	0.66	0.55	12.84
Std. Dev.	0.36	0.28	0.39	0.56	0.78	1.30	1.18	0.90	0.68	0.52	0.39	0.41	
Maximum	1.40	1.26	1.84	1.80	3.88	4.62	4.18	3.10	2.50	1.73	1.50	1.99	
Minimum	0.10	0.11	0.25	0.00	0.89	0.50	0.00	0.15	0.07	0.00	0.15	0.01	
Number of years													21.00
Number of years precipitation greater than mean													6
Number of years precipitation less than mean													15

SECTION 2.0 EAST CAMP SYSTEM

The East Camp Monitoring System consists of the Anselmo, Belmont, Granite Mountain, Kelley, Steward, Lexington and Pilot Butte Mines, the Berkeley Pit, and the mine workings associated with those sites. It also includes the East Camp bedrock system adjacent to the East Camp mines not affected by mine-water pumping and the shallow East Camp alluvial system (figure 2-1). The East Camp alluvial system is discussed first, followed by the East Camp bedrock system.

Section 2.1 East Camp Alluvial System

The East Camp alluvial monitoring system consists of a series of four different groups of wells. Each group of wells represents sites installed or monitored during different studies that have been incorporated in the BMFOU monitoring program. Water-level changes and monthly precipitation amounts are shown on hydrographs for selected wells. Water-quality results are shown and discussed for each well sampled. Unlike the water-level monitoring program, water-quality sampling does not occur at each East Camp monitoring well and takes place only twice per year.

Water-level conditions and water quality characteristics very by the various alluvial systems. Wells within or adjacent to historic mining activities show trend relating to the influence of those activities. Sites outside historic mining areas reflect conditions more typical of the regional hydrogeology.

Section 2.1.1 AMC-Series Wells

The locations of the Anaconda Mining Company (AMC) wells are shown on figure 2-2; table 2.1.1.1 lists the annual water-level changes for these sites. The revised monitoring program

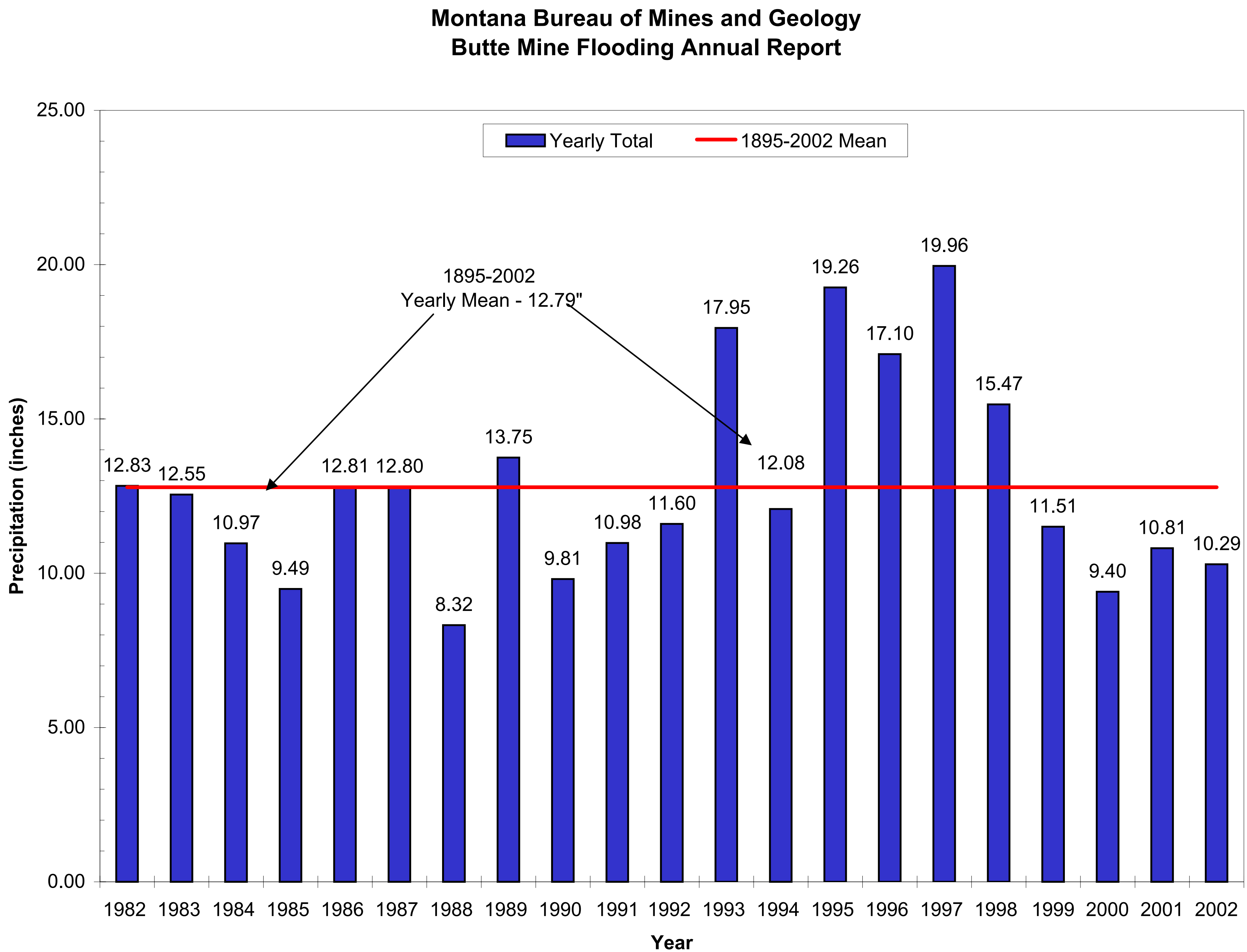


Figure 1-4. Yearly precipitation totals, 1982-2002, showing 1895-2002 yearly mean.

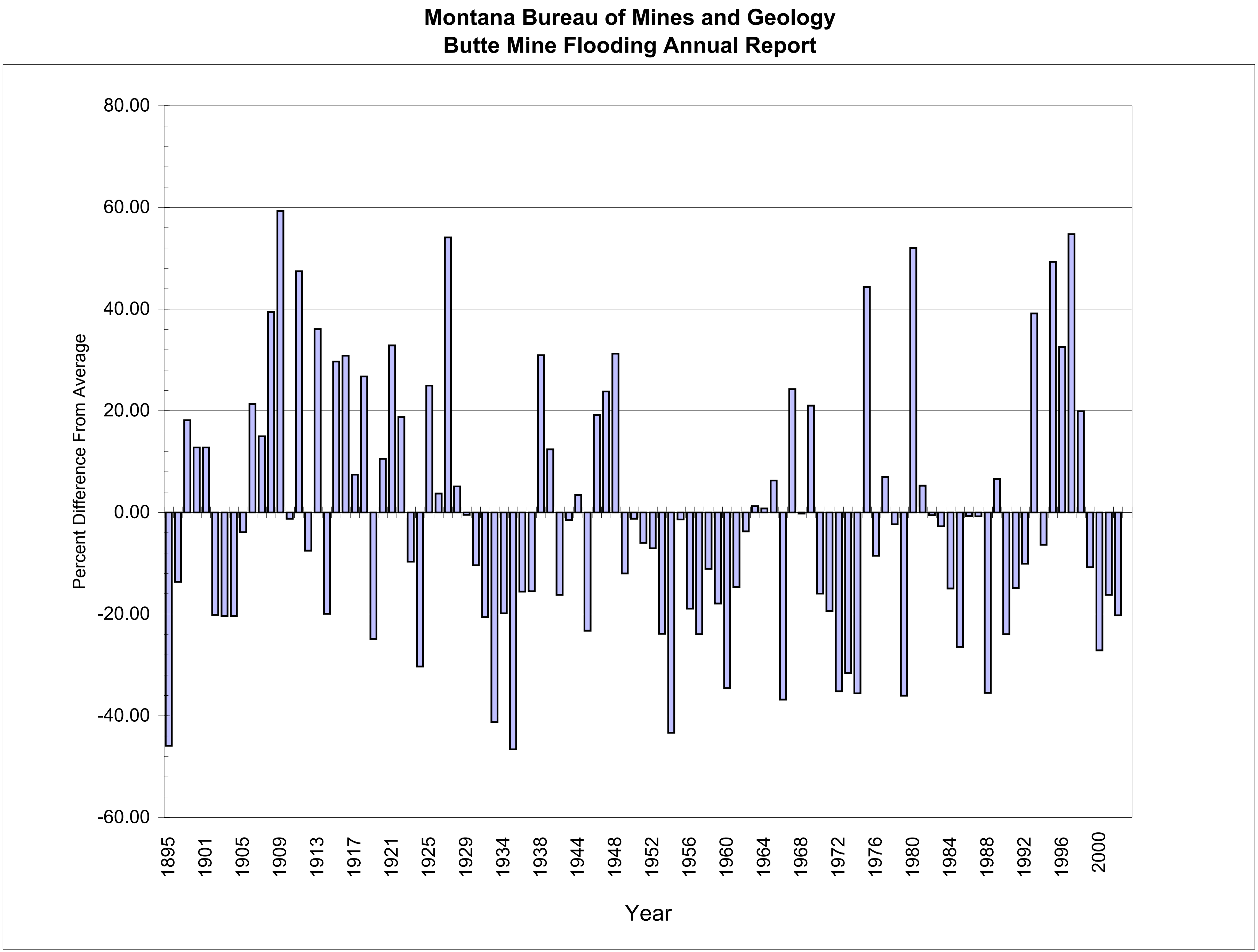


Figure 1-5. Percent precipitation variation from normal, 1895-2002

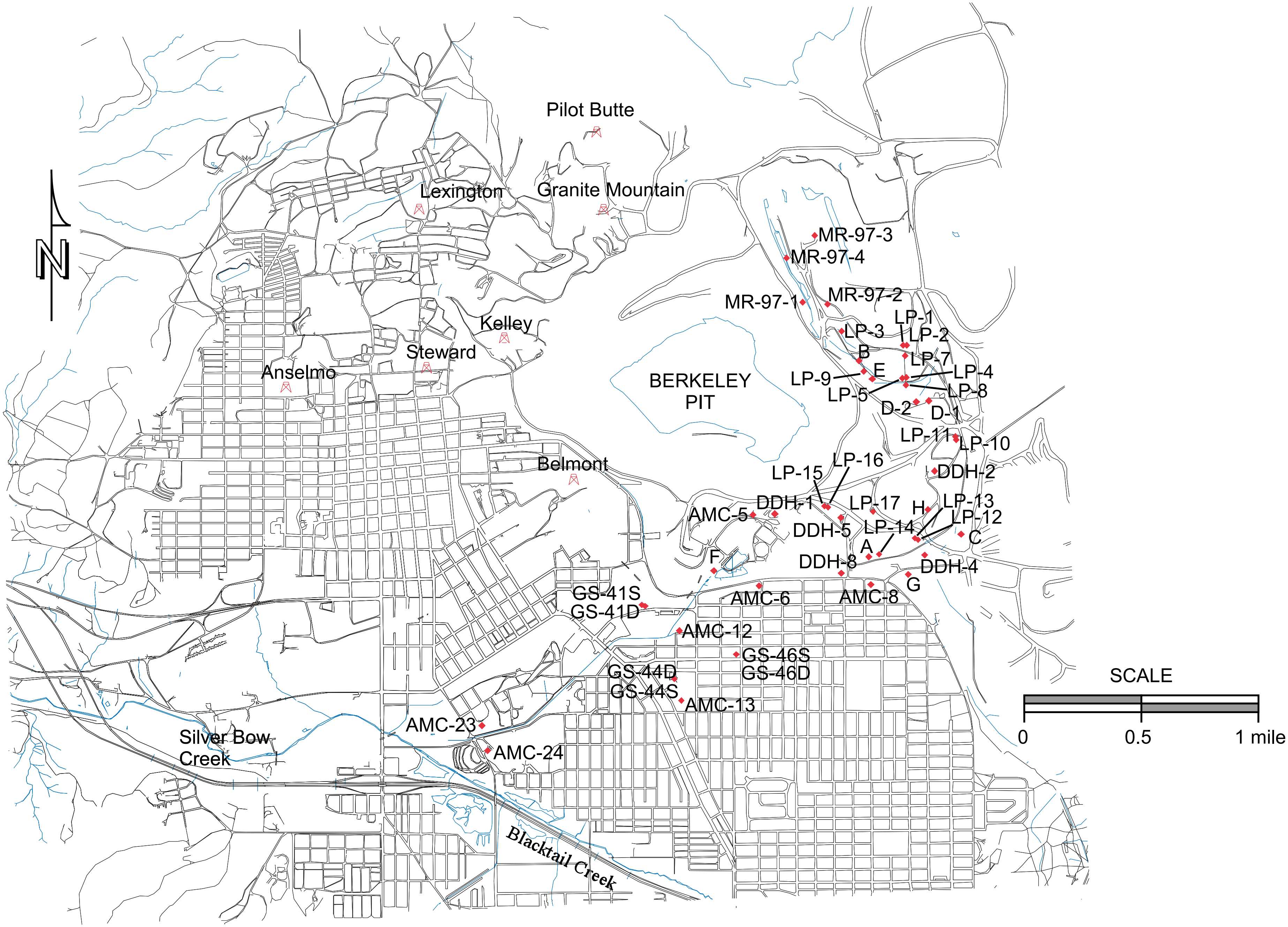


Figure 2-1. East Camp Monitoring Sites.

implemented through the CD removed wells AMC-11, AMC-23 and AMC-24 from the monitoring network; therefore no data is presented for those wells in this report. Water levels declined in 6 of the 7 wells, with one well remaining dry during 2002; however, the amount of decline was less than during 2001 in a majority of them.

Wells AMC-5, AMC-6, and AMC-8 are located south of the active mine area and the Butte Concentrator facility (figure 2-2). Well AMC-12 is located southwest of these wells. Hydrographs for wells AMC-5 and AMC-12 (figure 2-3) and AMC-6 and AMC-8 (figure 2-4) show the long-term trends in the shallow alluvial ground-water system south of the pit. Monthly precipitation amounts are shown as bars and are plotted on the right-hand y-axis.

There were no noticeable changes in water-level trends for wells AMC-5 and AMC-8. The water-level decline that began following the September 1998 Berkeley Pit landslide continued. Precipitation had very little effect on well-water levels and was very short lived. Wells AMC-6 and AMC-12 both showed greater response to precipitation events in 2001and 2002 than in the previous two years. These two wells are farther away from the area where the 1998 landslide occurred and it

Table 2.1.1.1 AMC-Series Wells, Annual Water-Level Changes, in feet

Year	AMC-5	AMC-6	AMC-8	AMC-10	AMC-12	AMC-13	AMC-15
1983	-23.75	-2.30	-4.90	DRY	0.20	0.60	-5.80
1984	-4.50	-2.55	-3.75	DRY	-1.80	-1.10	-3.40
1985	-3.40	-3.90	-3.00	DRY	-2.45	-1.85	-2.80
1986	8.70	3.90	-0.90	DRY	1.90	1.00	-2.10
1987	0.10	0.40	1.50	DRY	0.60	0.10	0.00
1988	0.20	-0.40	0.30	DRY	-0.10	-1.00	0.80
1989	-2.30	-0.80	-0.90	DRY	-0.20	-0.10	0.10
1990	0.20	0.10	0.30	DRY	1.10	0.00	-0.10
1991	0.00	0.30	0.80	DRY	-0.60	0.30	-0.30
1992	0.40	-0.40	0.50	DRY	-0.30	0.00	-0.10
1993	0.40	0.70	0.80	DRY	1.10	1.00	-0.40
1994	0.64	0.53	0.91	DRY	-0.19	-0.50	0.96
1995	0.64	1.01	0.51	DRY	1.23	1.13	0.97
1996	-0.05	0.62	2.14	DRY	0.74	0.69	2.60
1997	1.80	1.47	2.24	DRY	1.20	0.70	2.80
1998	-1.52	0.42	1.15	DRY	0.18	0.09	0.58
1999	-1.56	-2.03	-2.45	DRY	-1.56	-1.09	-1.50
2000	-2.46	-2.56	-3.88	DRY	-1.77	-1.17	-3.73
2001	-1.89	-1.92	-3.03	DRY	-0.55	-0.36	-2.34
2002	-0.89	-1.25	-1.77	DRY	-0.98	-0.73	-1.65
Net Change	***-29.24***	***-8.66***	***-13.43***	***0.00***	***-2.25***	***-2.29***	***-15.41***

is possible the influence of this landslide on local water levels is lessening. Water levels declined

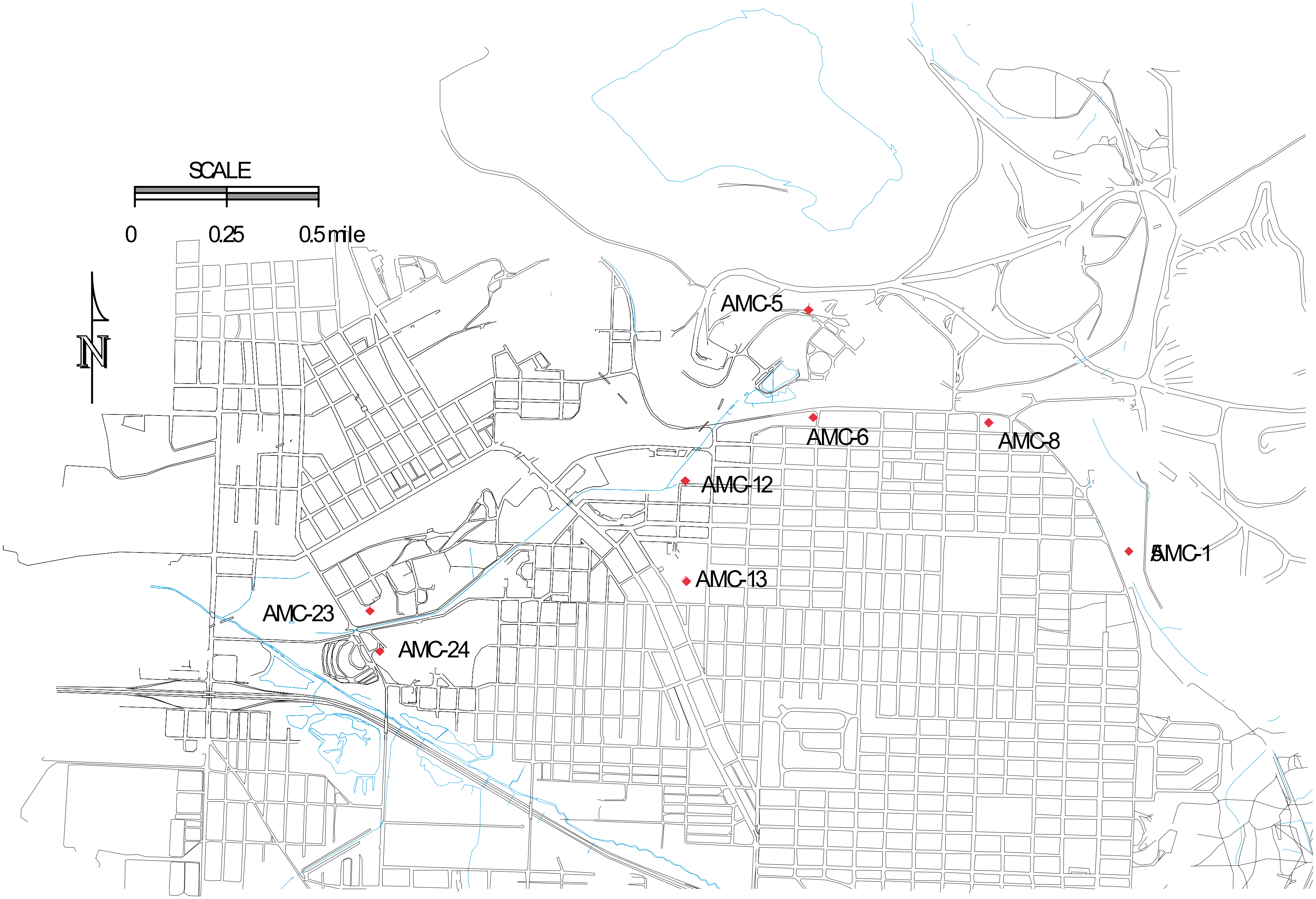


Figure 2-2. AMC Well Location Map.

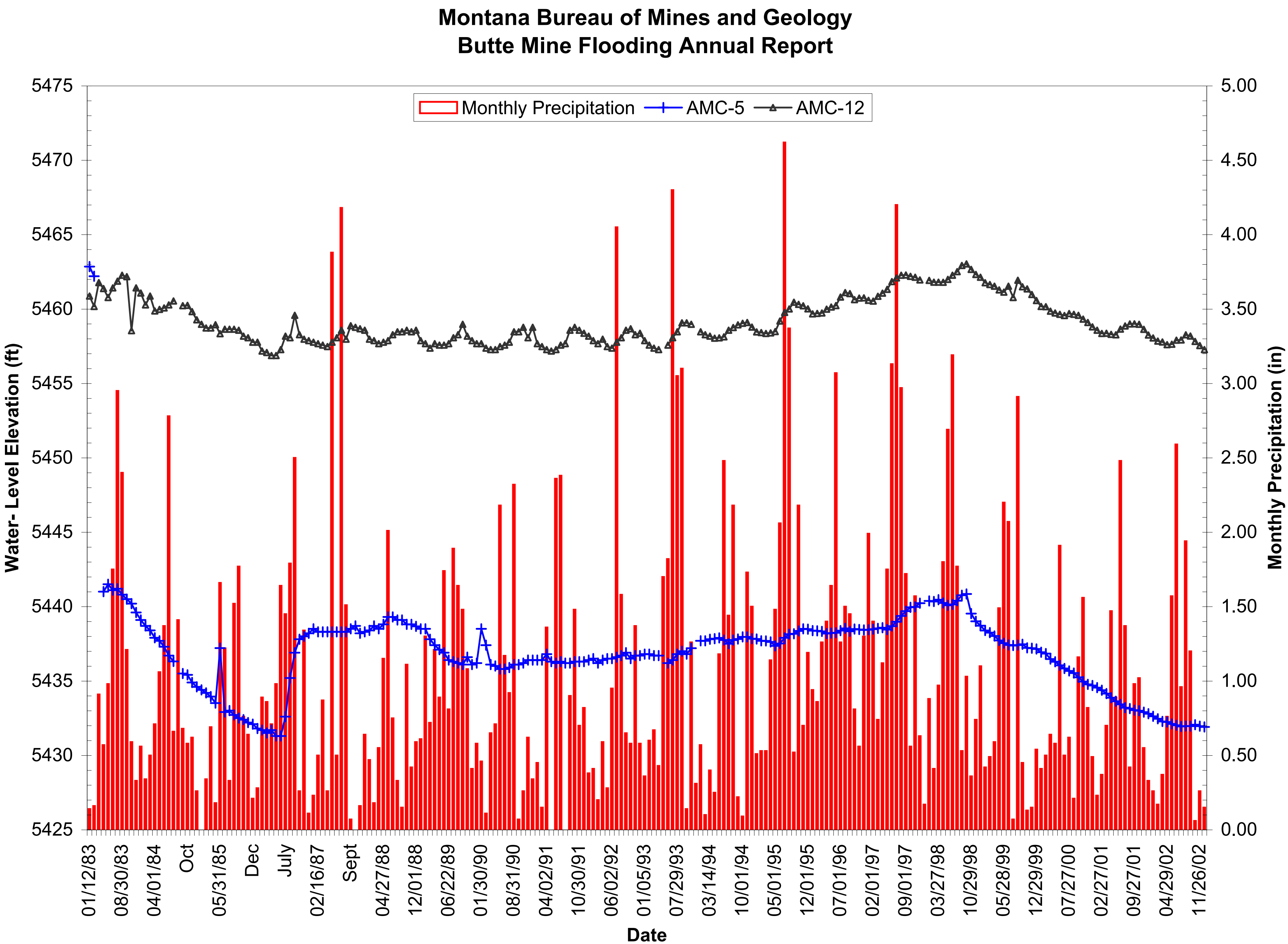


Figure 2-3. Water-level hydrographs for AMC-5 and AMC-12 wells.

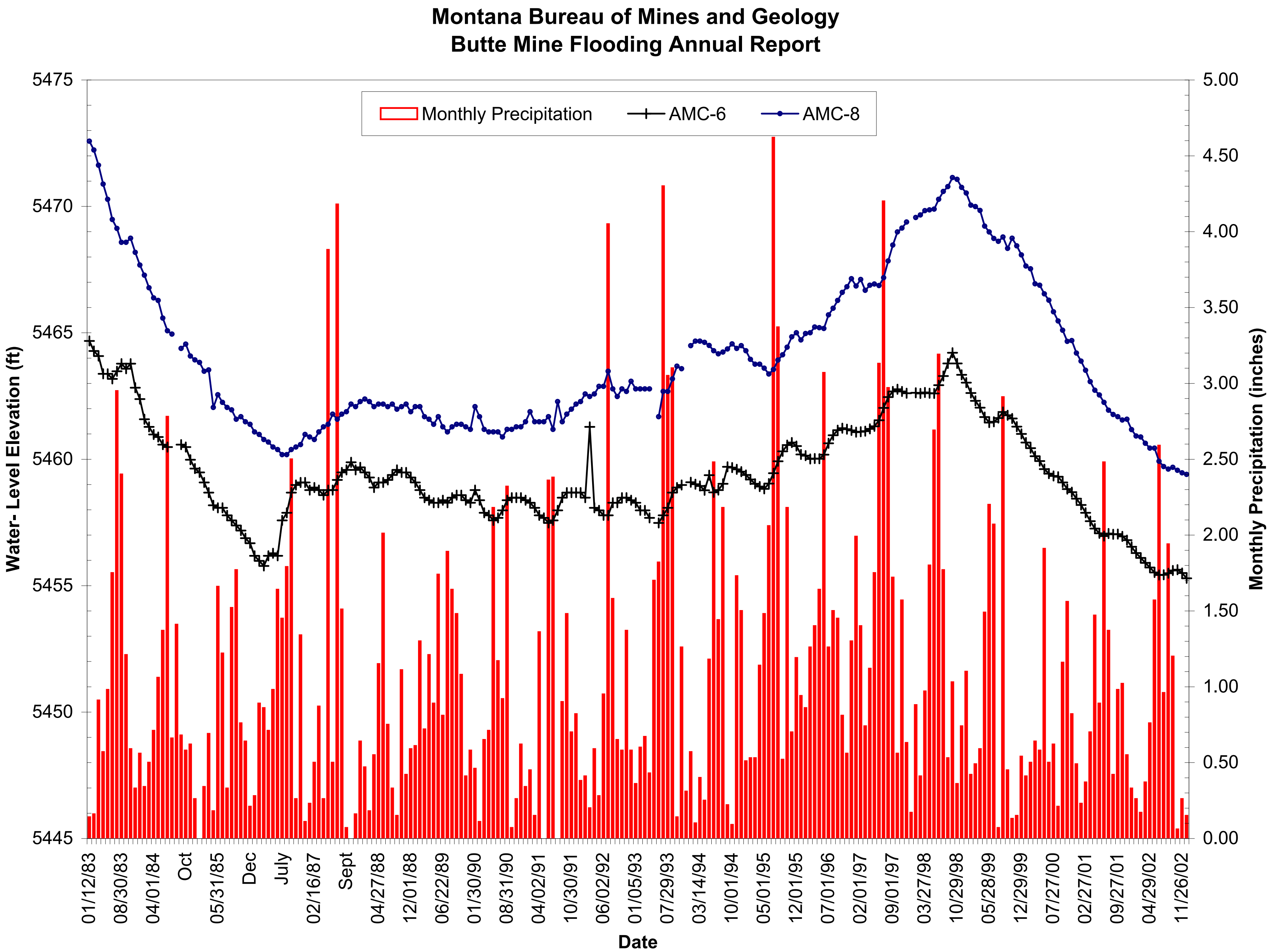


Figure 2-4. Water-level hydrographs for AMC-6 and AMC-8 wells.

between 0.89 foot and 1.77 feet during 2002 in these four wells. These are less than 2001 declines, with the exception of well AMC-12, whose decline was over 0.4 foot greater.

Well AMC-13 is located on the west side of Clark's Park, south of wells GS-44S and GS-44D. This well's hydrograph shows both a response to precipitation events and lawn watering (figure 2-5a). Water levels began to rise in the spring and continued throughout the summer, before starting to decline in the fall.

Well AMC-15 is located on the west side of the Hillcrest waste dump (figure 2-2) in an area where reclamation has taken place. Water in this well is very deep (less than 90 feet) compared to the other AMC wells, and the hydrograph reflects this. There were minor seasonal changes in water levels for a number of years. However, the recent below-normal precipitation is shown by the steep decline in water levels the past three years (figure 2-5b). This well did not show any significant response to precipitation. However, the water-level decline appeared to be leveling off in the later part of 2002.

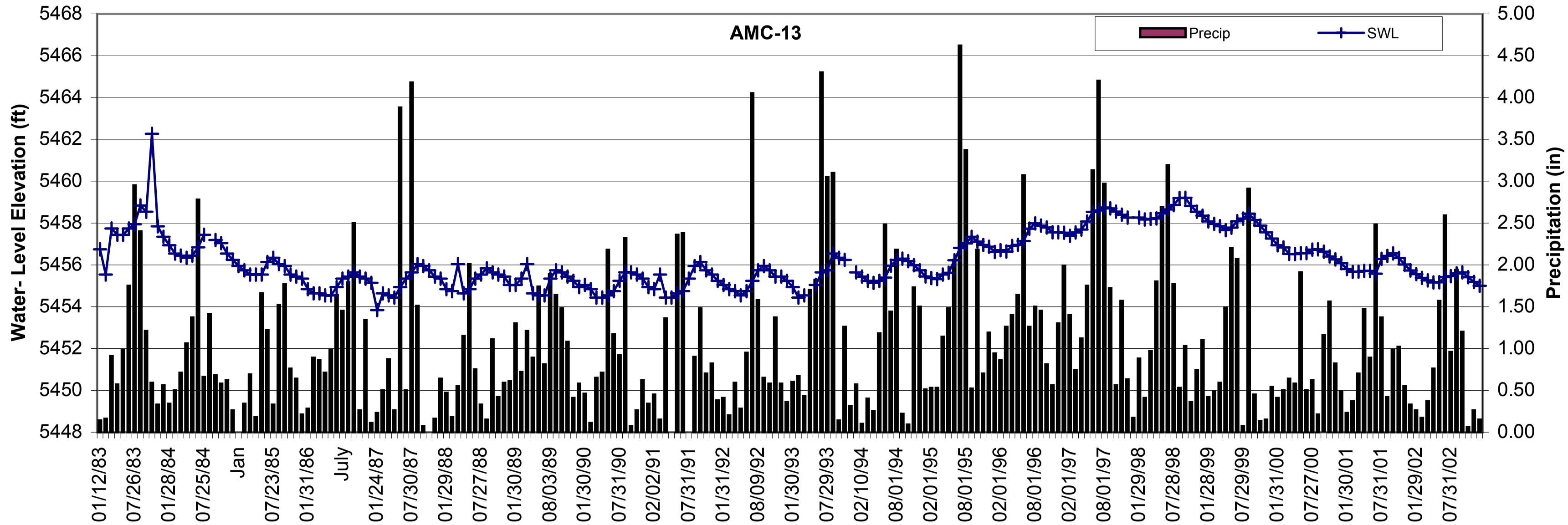
Section 2.1.1.2 AMC Series Wells Water Quality

Concentration trends of the 2002 data collected from the AMC-series wells are summarized in Table 2.1.1.2. Well AMC-5, just south of the Berkeley Pit, has exceeded MCLs and SMCLs throughout the period of record. Concentrations of zinc, copper, and iron have shown a slight downward trend. Conversely, arsenic and sulfate have shown wide variation in concentrations and, since 1994, have shown a slight increase.

Wells AMC-6 and AMC-8 are just south of the Berkeley Pit, generally coincident with the ground-water divide. Concentrations of most dissolved constituents are generally higher in the down-gradient well, AMC-6. Both wells show variable but similar trends in concentrations except for sulfate. The concentration of sulfate in AMC-6 (figure 2.6) has generally declined throughout the period of record (2002 sample: 283 mg/L), while in AMC-8 sulfate has increased over the same period (2002 sample: 366 mg/L). Arsenic concentrations have increased over the past several years in both wells; 2002 data indicated a continuation of that trend, but concentrations are less than 10 μg/L.

2.5(a)

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report



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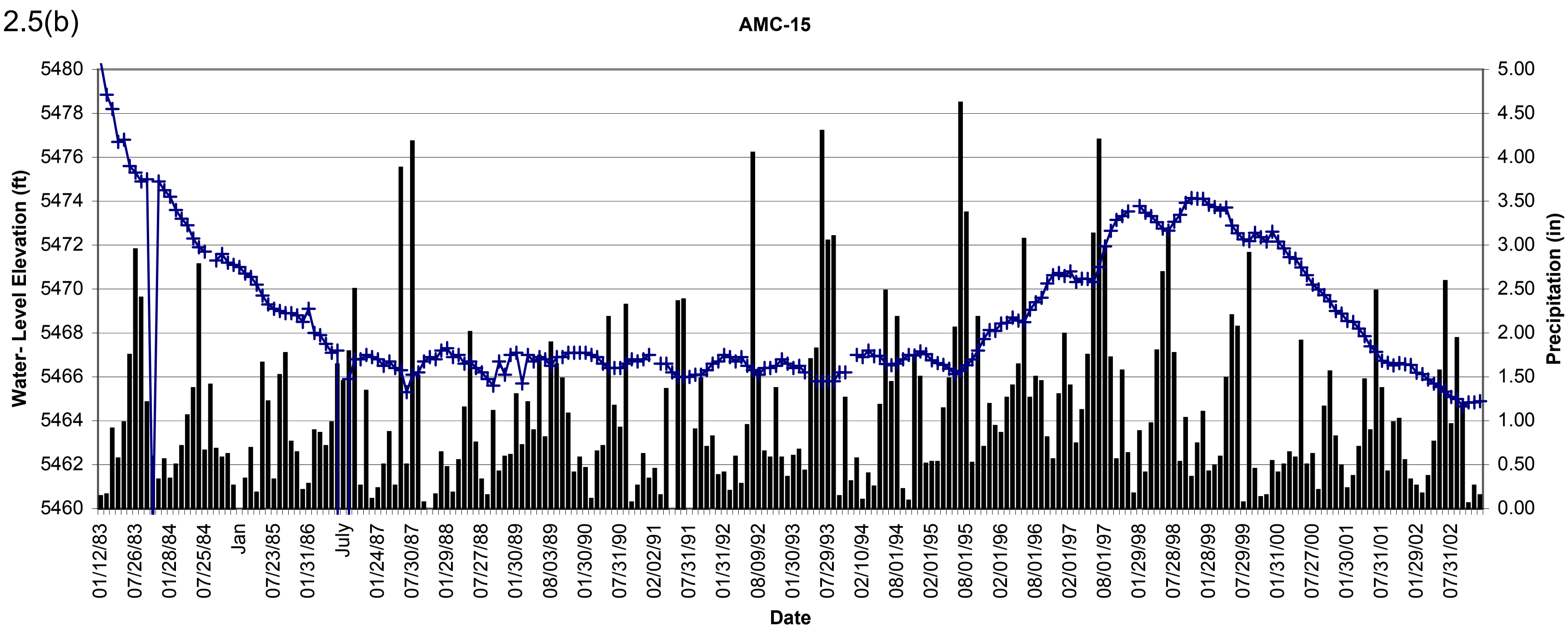
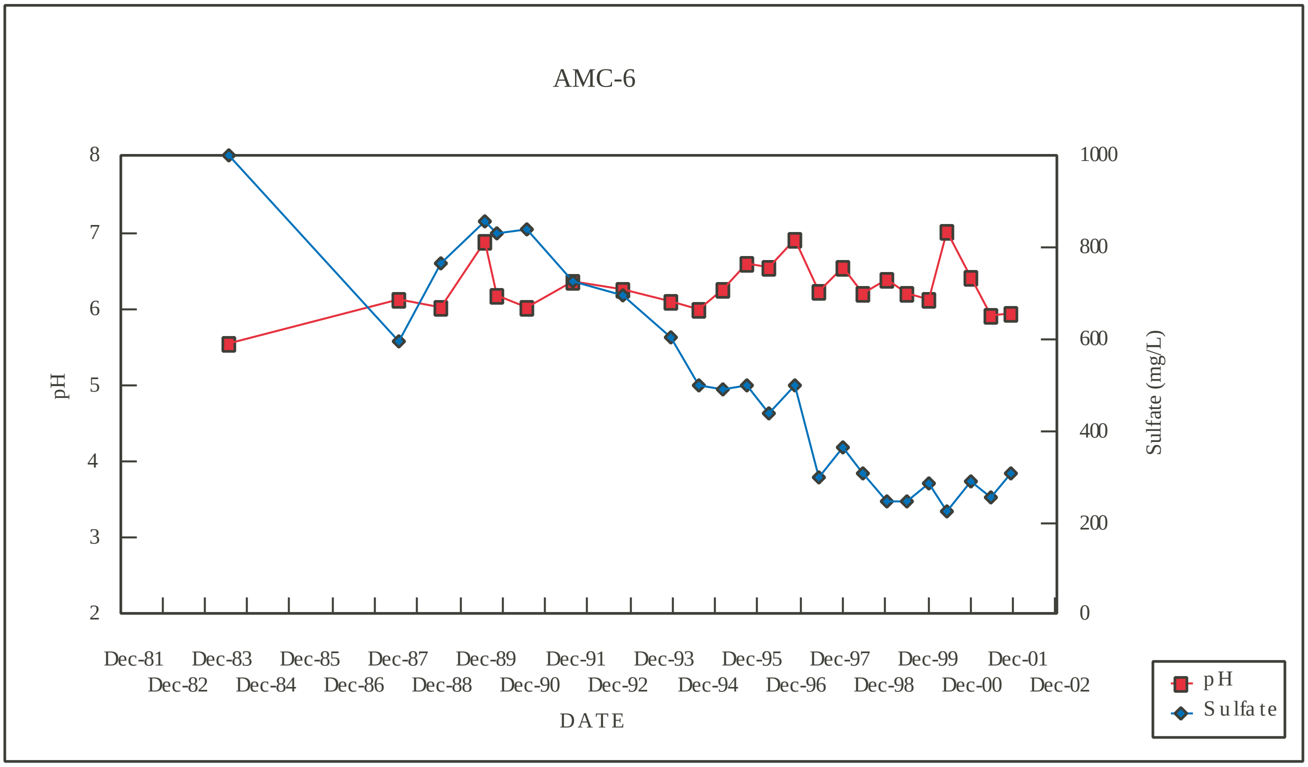


Figures 2-5 a and b. Water-level hydrographs for AMC-13 (a), and AMC-15 (b) wells.



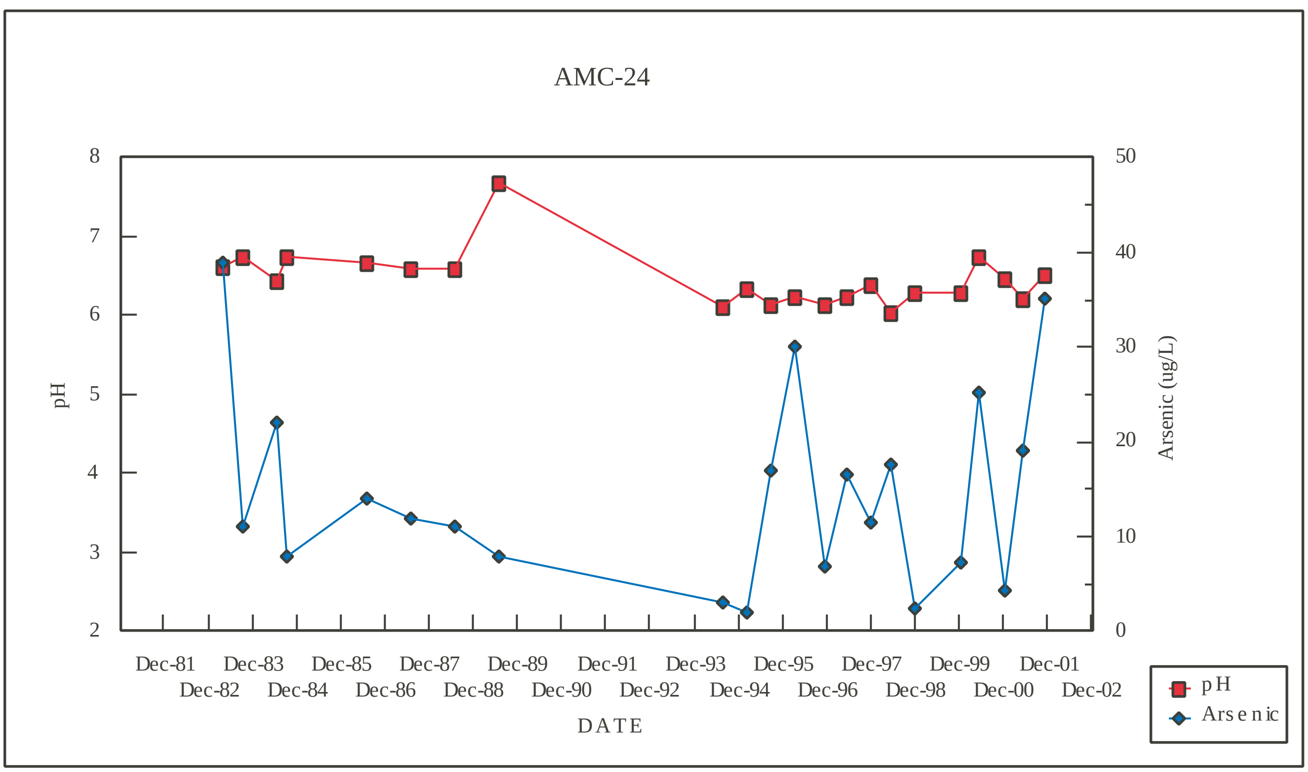


Figure 2-6. Sulfate concentrations for AMC-6 and arsenic concentrations for AMC-24.2

Table 2.1.1.2 Exceedences and Trends for AMC Series Wells, 2002

Well Name	Exceedences	Concentration Trend	Remarks
AMC-5	Y	variable	may be showing reversal of trend for sulfate increase
AMC-6	Y	downward	slight downward trend continues
AMC-8	Y	variable	
AMC-12	Y	variable	not sampled in 2002
AMC-13	Y	variable	net change is small
AMC-15	Y	variable	only sulfate exceeds SMCL; net change is small
AMC-23	Y	variable	net change is small for all constituents
AMC-24	Y	variable	sulfate increased from 400 to 1100 mg/L; the highest concentration in this well since 1982

Wells AMC-13 and AMC-15 show little change in concentrations in the most recent data. Sulfate concentrations exceed the SMCL in both wells (2002 sample: 445 and 310 mg/L, respectively). Well AMC-12 was not sampled in 2002. Well AMC-24 (figure 2.6) continues to show the greatest variation in trend as well as the highest overall concentration of arsenic (2002 sample: 24.1 µg/L).

Zinc concentrations in the AMC-series wells range from 57,200 µg/L in AMC-5 near the Berkeley Pit to about 30 µg/L in AMC-15 on the east margin of the valley. No strong trends are apparent in any wells; most show a slight downward trend over the period of record. Copper concentrations range from about 13,000 µg/L in AMC-5 to less than 10 µg/L in AMC-13, AMC-15, and AMC-24.

Section 2.1.2 LP-Series Wells

The locations of the LP series monitoring wells are shown on figure 2-7. As discussed in Duaime and others (1998), these wells were installed in 1991 as part of the BMFOU RI/FS study. Water-level monitoring and sampling of the LP series wells continued. Table 2.1.2.1 contains a summary of annual water-level changes for these 17 sites. Well LP-11 was plugged and abandoned in 2001; well LP-03 was plugged and abandoned in 2002 to make room for the HSB water-treatment plant

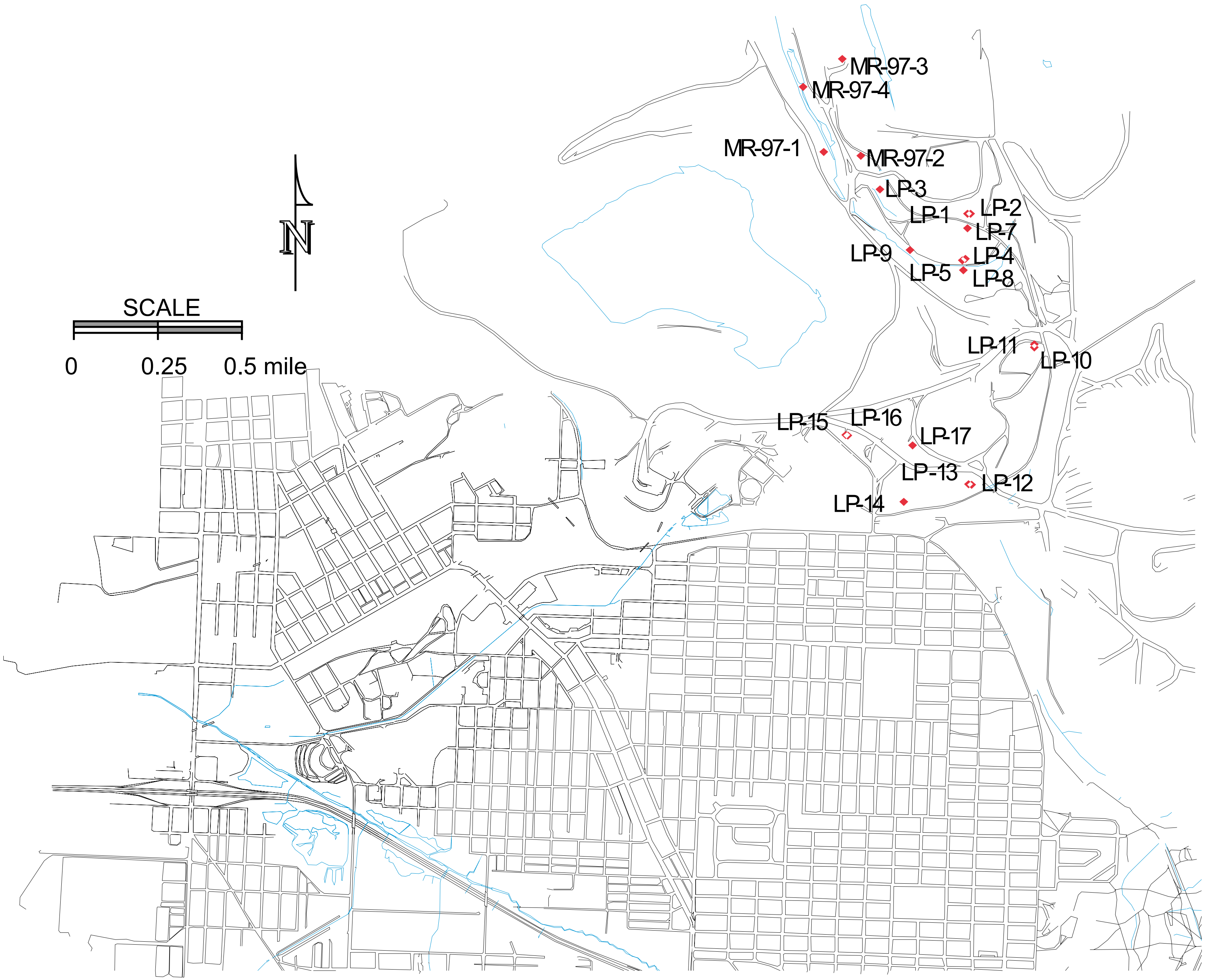


Figure 2-7. LP series and MR97 Wells Location Map.

construction. Therefore, the water-level change shown for this well is for the first 6 months of 2002 only. Two other wells (LP-06 and LP-07) remain dry. Water levels declined in 14 of the remaining wells during 2002. Water levels had a net decline in all 17 of these wells, ranging from 3.26 feet to 42.96 feet in wells LP-14 and LP-08, respectively. Monitoring data through 2002 indicated that water levels in wells located to the north of the Pittsmont Waste Dump (LP-1 through LP-09) continued to decline more rapidly than in wells to the east and south of the Pittsmont Dump. These declines were not as great, however, as in previous years.

Table 2.1.2.1 Annual Water-Level Change in LP-Series Wells

Year	LP-01	LP-02	LP-03	LP-04	LP-05	LP-06	LP-07	LP-08	LP-09
1991	1.23	-0.91	-2.02	1.38	4.35	-0.46	-	-	-0.70
1992	-1.14	-1.56	-0.66	-1.75	-1.08	0.80	-3.79	-3.78	-7.16
1993	-0.91	-1.69	1.84	-1.69	-2.42	-0.53	-3.06	-4.83	-2.24
1994	-0.53	-0.80	-1.61	-0.57	-1.42	-2.28	-1.03	-2.11	-2.90
1995	-0.08	-0.19	-1.74	2.94	0.34	0.47	4.91	4.30	3.35
1996	-2.05	-2.00	-0.73	-1.28	-3.40	2.01	-4.30	-1.14	-1.49
1997	-1.58	-1.86	-0.09	-1.73	-3.32	-1.37	-2.24	-2.63	-0.29
1998	0.12	0.23	-2.03	1.01	-0.03	-0.58	2.44	0.99	1.60
1999	-2.24	-1.76	-7.44	-2.64	-3.15	-1.65	-6.47	-3.52	-3.77
2000	-7.55	-7.16	-5.45	-10.83	-7.87	-0.20	-3.10	-14.03	-13.28
2001	-5.13	-4.73	-9.51	-8.88	-5.47	Dry	Dry	-12.10	-3.04
2002	-5.21	-3.91	-2.01*	-6.03	-4.86	Dry	Dry	-4.11	-3.46
Net Change	***-25.07***	***-26.34***	***-31.45***	***-30.07***	***-28.33***	***-3.79***	***-16.64***	***-42.96***	***-33.38***

Year	LP-10	LP-11	LP-12	LP-13	LP-14	LP-15	LP-16	LP-17
1991	-	-	-	-	-	-	-	-
1992	-0.50	-1.83	0.31	-0.07	0.70	0.54	0.89	-
1993	-0.83	-2.78	1.42	1.11	1.18	1.62	1.83	-
1994	-2.14	1.65	-1.41	-0.47	-0.09	0.26	-1.16	-
1995	-0.57	-0.23	-0.16	0.43	0.18	1.89	3.57	3.10
1996	1.20	0.23	1.87	1.74	2.07	1.79	1.77	1.66
1997	0.23	-0.09	2.42	2.24	2.64	1.99	1.77	2.32
1998	0.92	0.07	1.00	-0.62	0.39	-7.90	-9.69	-2.41
1999	-2.05	-2.12	-2.94	-2.36	-2.73	-4.39	-4.60	-3.95
2000	-1.37	-0.28	-3.60	-2.93	-3.64	-1.73	-2.18	-2.86
2001	0.51	P&A*	-1.16	-1.30	-2.31	-0.72	-1.18	-1.50
2002	-0.15	P&A*	-1.83	-1.21	-1.65	-0.68	-0.86	-0.67
Net Change	***-4.75***	***-5.38***	***-4.08***	***-3.44***	***-3.26***	***-7.33***	***-9.84***	***-4.31***

(*) Plugged and abandoned

The water-level declines in the areas adjacent to wells LP-06 and LP-07 are greater than those shown in Table 2.1.2.1, as both of these wells are currently dry. The water levels measured in these wells are actually standing water in the well bottom, as the level had dropped below the wells screened intervals.

The steep decline noted in some of these wells in 1999 following MR's deactivation of the leach pads, continued throughout 2002. Based upon observed water levels since 1999, the operation of the leach pads had a major impact on the alluvial aquifer in this area. Water levels in these wells show only marginal influence, if any, from precipitation events.

Figures 2-8 through 2-10 show hydrographs from seven representative wells, along with monthly precipitation totals. Wells LP-01 and LP-02 are located to the north of the site near the base of various leach pads and are screened in two different intervals. Well LP-01 is screened deeper than well LP-02. The wells are screened at depths of 129 to 159 feet and 177 to 197 feet, respectively, and are completed in the deeper portion of the alluvial aquifer. Water-level trends are similar in these two wells (figure 2-8), however, the water level in well LP-02 rose slightly after several 2002 precipitation events. The downward water-level trend is very evident in both of these wells.

Wells LP-04 and LP-07 are located south of wells LP-01 and LP-02 and north of the Pittsmont Dump (figure 2-7). These wells are completed at different depths also. Well LP-04 is screened from 125 to 145 feet below ground surface, while well LP-07 is screened from 90 to 95 feet below ground surface. Based upon these well-completion depths, well LP-07 would be considered to be completed in the upper portion of the alluvial aquifer, while well LP-04 would be considered to be completed in the deeper portion of the alluvial aquifer. Water levels declined in well LP-04 during 2002 (figure 2-9). There was no noticeable effect of precipitation on the water level in this well. The water level in well LP-07 continues to be below the bottom of this well's casing, meaning the well has gone dry. This occurred about March 2000. Therefore, the total water-level decline in this area is not known.

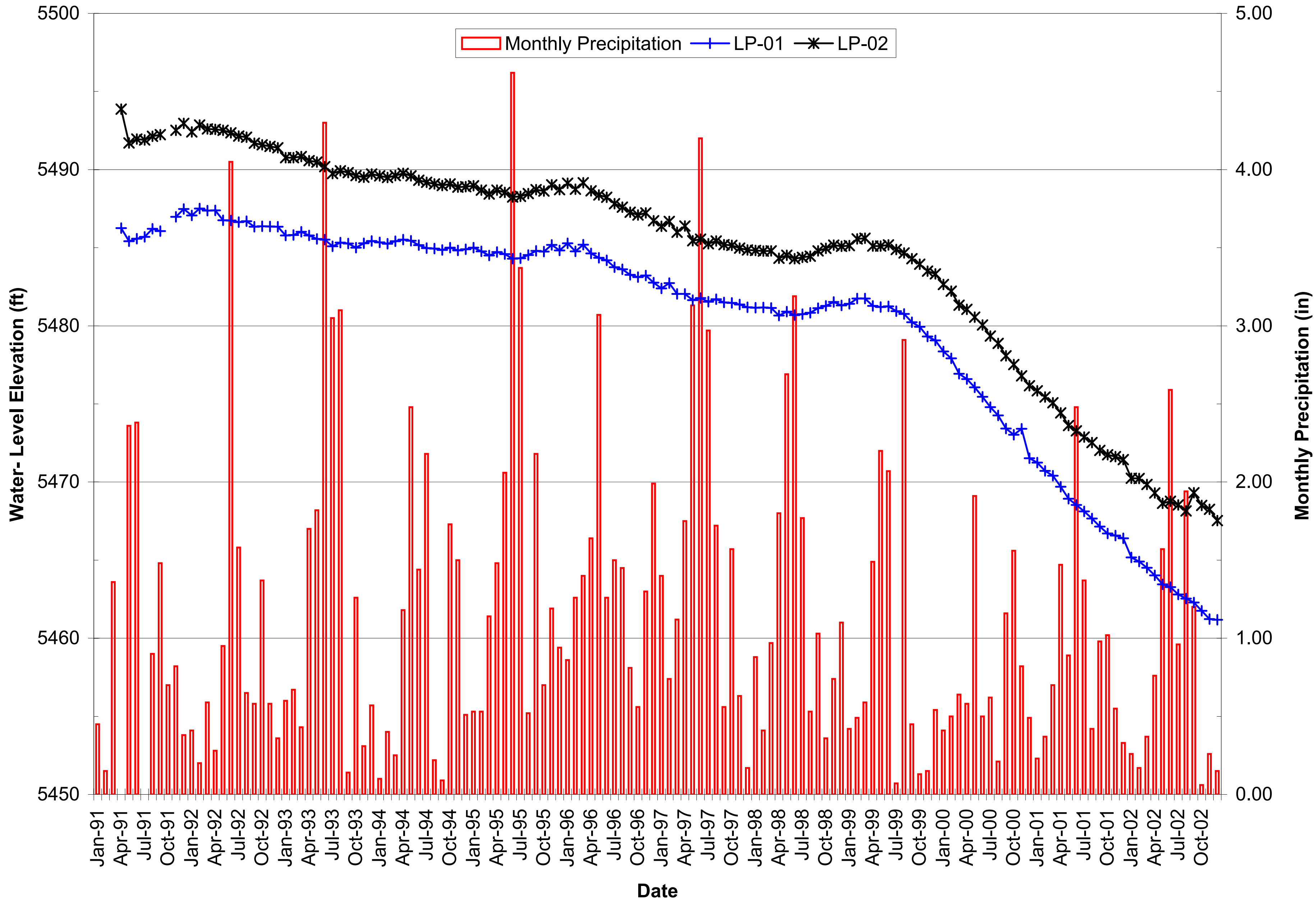


Figure 2-8. Water-level hydrographs for LP-01 and LP-02 wells.

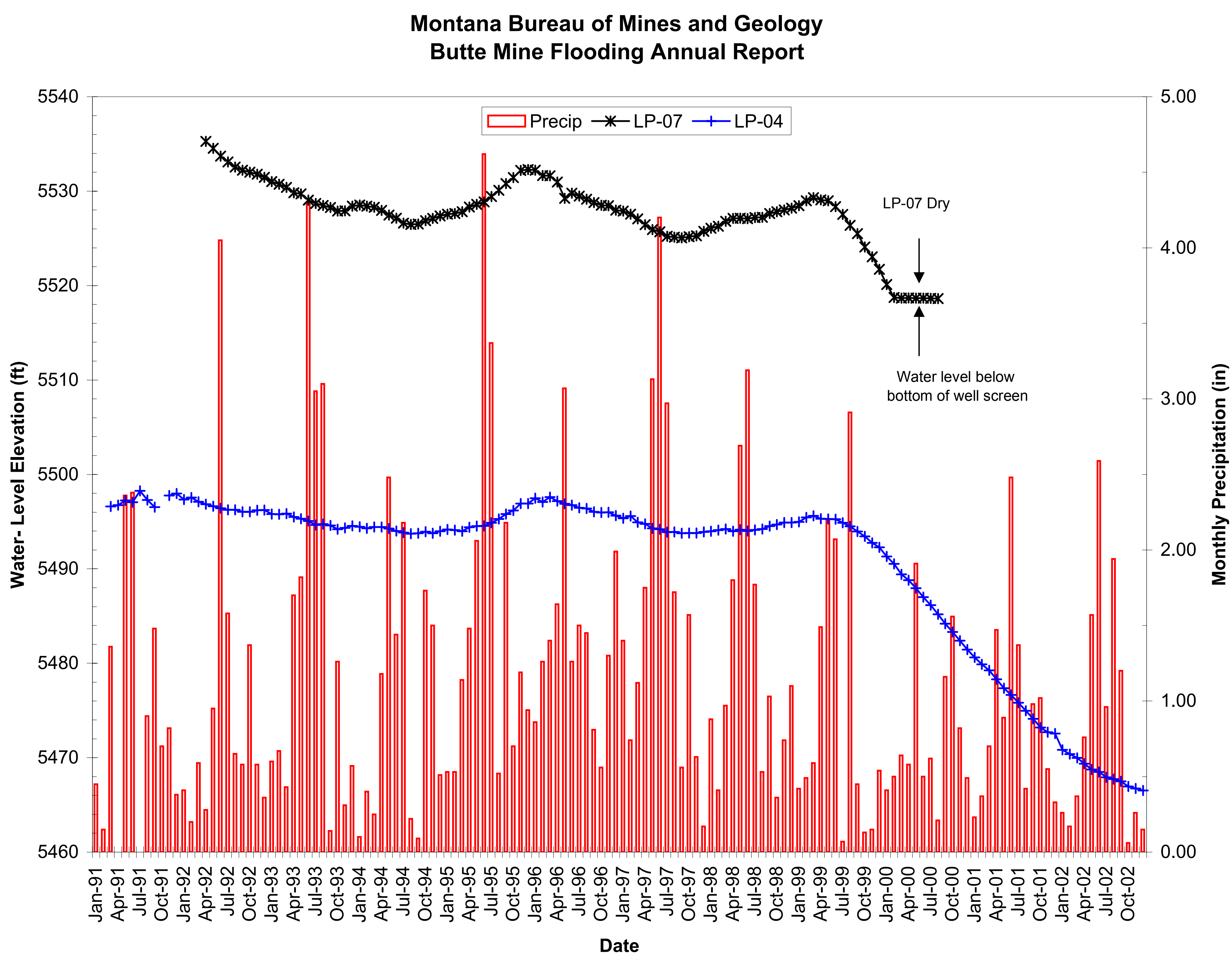


Figure 2-9. Water-level hydrograph for LP-04 and LP-07 wells.

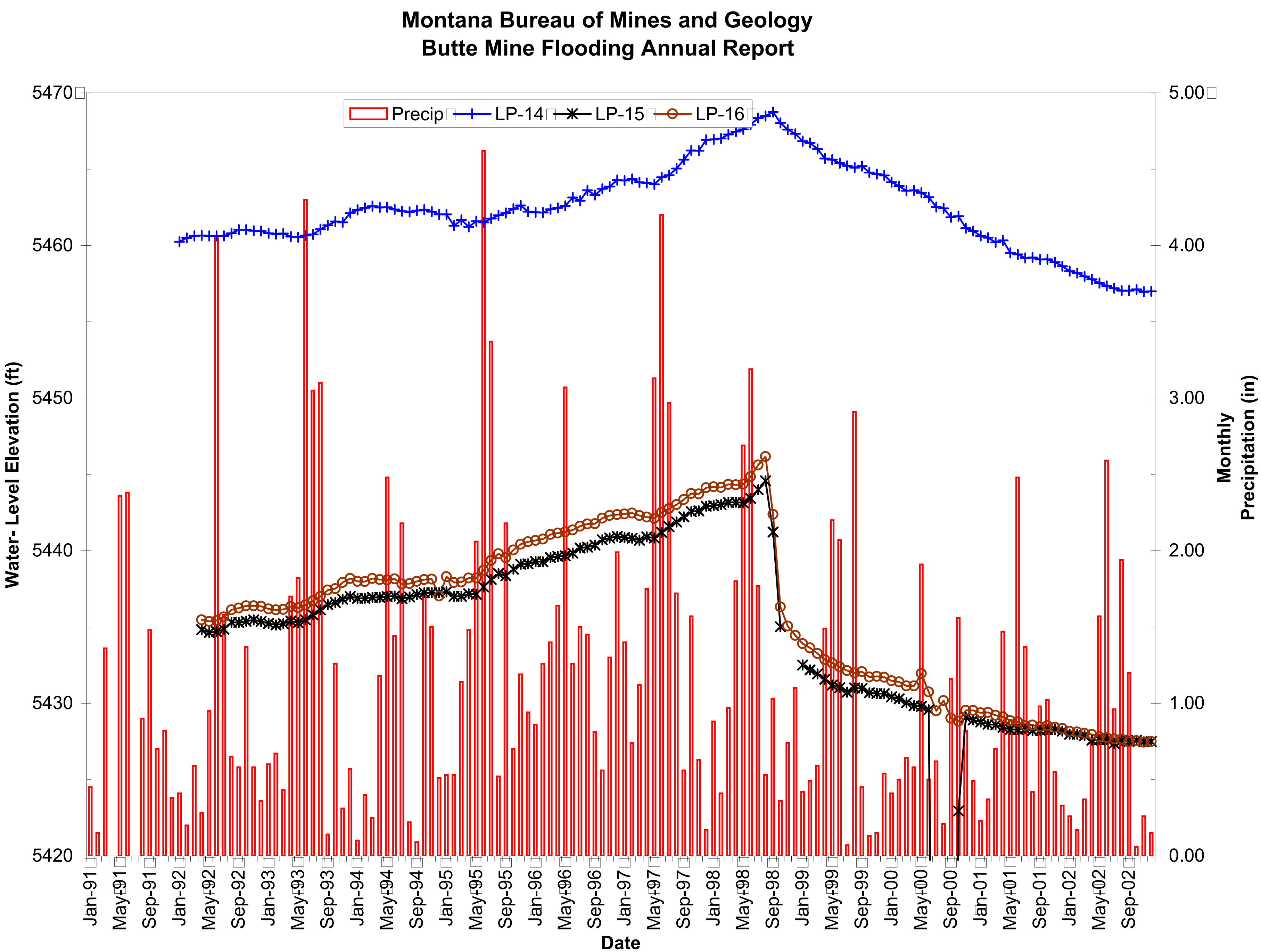


FIgure 2-10. Water-level hydrograph for LP-14, LP-15, and LP-16 wells.

Wells LP-14, LP-15, and LP-16 are located southwest of the Pittsmont Dump (figure 2-7). A consistent increase in water levels occurred in these wells following their installation in 1992, until the Berkeley Pit landslide of 1998 (figure 2-10). Since that landslide, water levels have continued to decline in a similar way in all three of these wells. Wells LP-15 and LP-16 are located near one another and were completed as a nested pair, with well LP-15 being screened from a depth of 215 to 235 feet below ground surface and well LP-16 screened from 100 to 120 feet below ground surface. Water-level declines are similar in all three wells. The magnitude of the 2002 declines was less than previous years.

MR installed a pump in well LP-15 shortly after the 1998 landslide in an attempt to stabilize the slide area by lowering water levels and relieving pressure along the southeast wall of the Berkeley Pit. They operated the pump in well LP-15 from late May through October 2000, pumping more than 8 million gallons of water. The pump did not operate during 2001 or 2002.

The general observation made in the last several yearly reports, that wells between the leach pads and Pittsmont Waste Dump were affected by leach-pad operations, including the 1999 leach-pad dewatering and historic-mine dewatering, remains true. The trend toward lower water levels seen since 1999 continued in 2002. Water levels in the LP-series wells were either controlled by the operation and subsequent dewatering of the leach pads, or by the depressed water levels in the Berkeley Pit, or a combination of both. The influence of precipitation is minimal at most, on any of these wells.

An alluvial aquifer potentiometric map (figure 2-11) constructed using December 2002 water levels, shows how alluvial waters are flowing towards the Berkeley Pit from the north, east and south. Water contaminated by historic mining activities (Metesh, 2000) is flowing towards and into the Berkeley Pit, ensuring that there is no outward migration of contaminated water into the alluvial aquifer.

Section 2.1.2.1 LP-Series Wells Water Quality

Current water-quality monitoring of the LP-series wells is restricted to those wells east and south of the Pittsmont Dump (figure 2-6). Water-quality trends in 2002 reflected the same trend as the

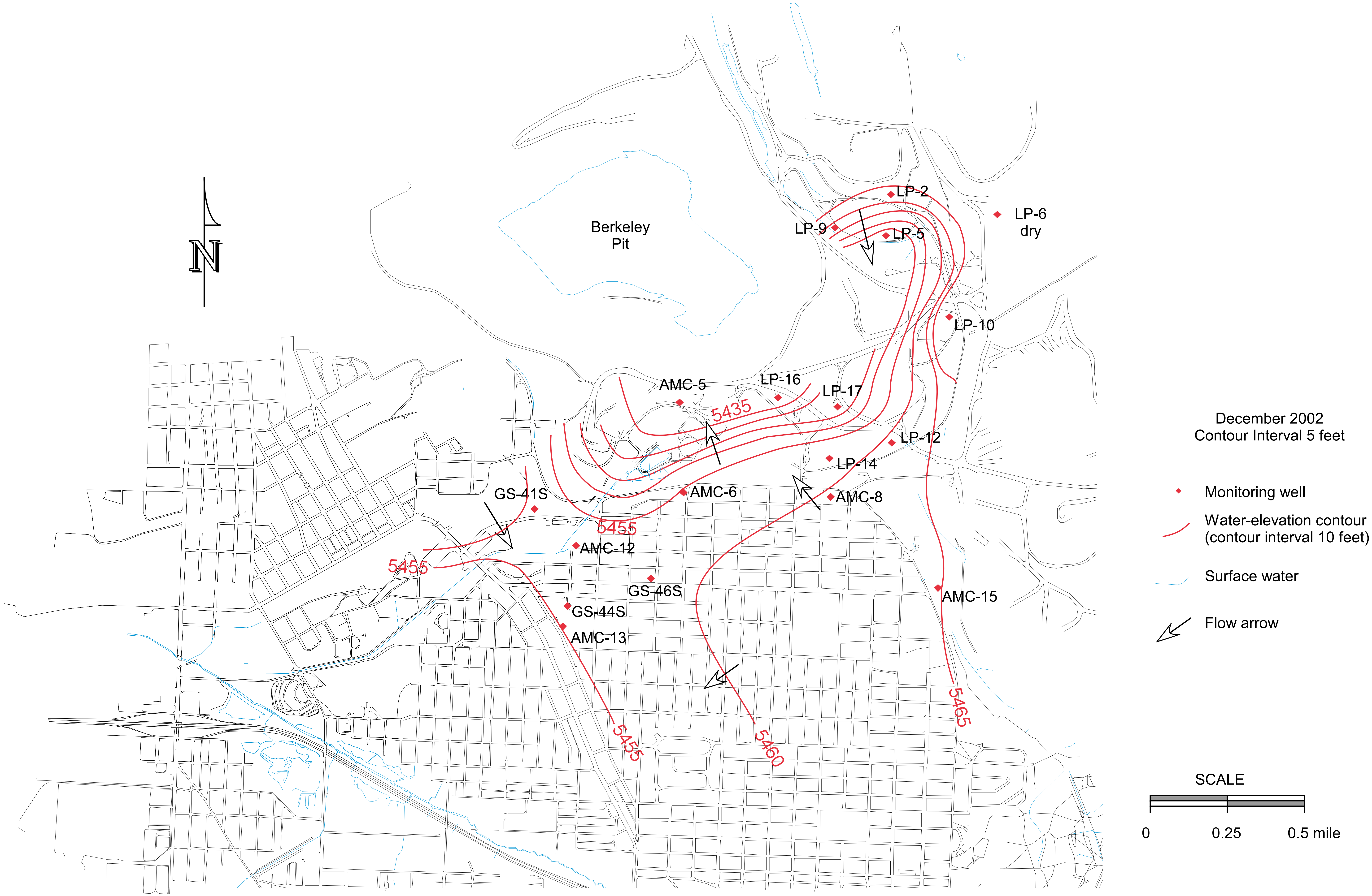


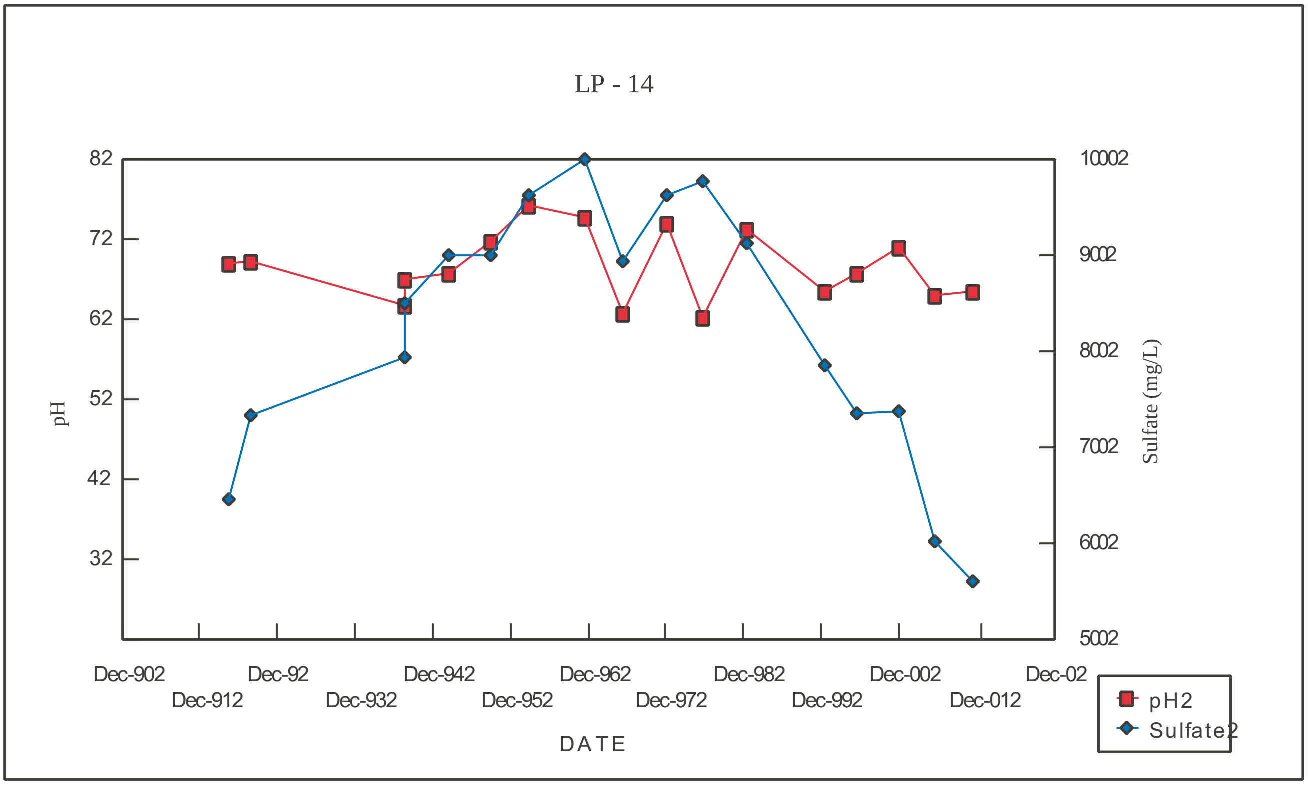
Figure 2-11. Alluvial Aquifer Potentiometric Map, December 2002; arrows indicate direction of ground-water flow implied by contours (contour interval is 5 feet).

previous year; concentration trends are summarized in Table 2.1.2.2. The most notable wells are near the southeast corner of the Berkeley Pit where, as discussed previously, water levels have been declining since the landslide in 1998. Sulfate concentrations in wells LP-16 and LP-14 have reversed from an upward trend since 1998, and have decreased about 450 mg/L since the landslide; in 2002, concentrations increased slightly in both wells. Well LP-17 exhibited decreasing sulfate concentrations until 1998 when the trend reversed and concentrations increased by about 500 mg/L. Since 2000, water-quality data from LP-17 suggests another reversal of trend toward decreasing sulfate concentrations; the trend continued in 2002. Figure 2-12 shows sulfate concentrations over time for wells LP-14 and LP-17.

Table 2.1.2.2 Exceedences and trends for LP Series Wells, 2002

Well Name	Exceedences (±1)	Concentration Trend	Remarks
LP-10	N	variable	no significant changes in 2002
LP-12	Y	variable	no significant changes in 2002; downward trend in sulfate continues
LP-13	Y	variable	downward sulfate trend continues in 2002
LP-14	Y	variable	slight increase in sulfate concentration
LP-15	Y	variable	net change is small for most analytes
LP-16	Y	variable	sulfate trend similar to that of LP-14
LP-17	Y	variable	no significant changes in 2002

Dissolved copper concentrations range from about 200 µg/L in well LP-10 to about 4,000 µg/L in LP-17. Arsenic concentrations are generally less than 10 µg/L in all of the wells sampled. Iron concentrations are less than 1 mg/L in all of the 2002 samples. Zinc concentrations are below the SMCL of 5,000 µg/L in all of the LP-series wells except LP-17, which has a concentration of about



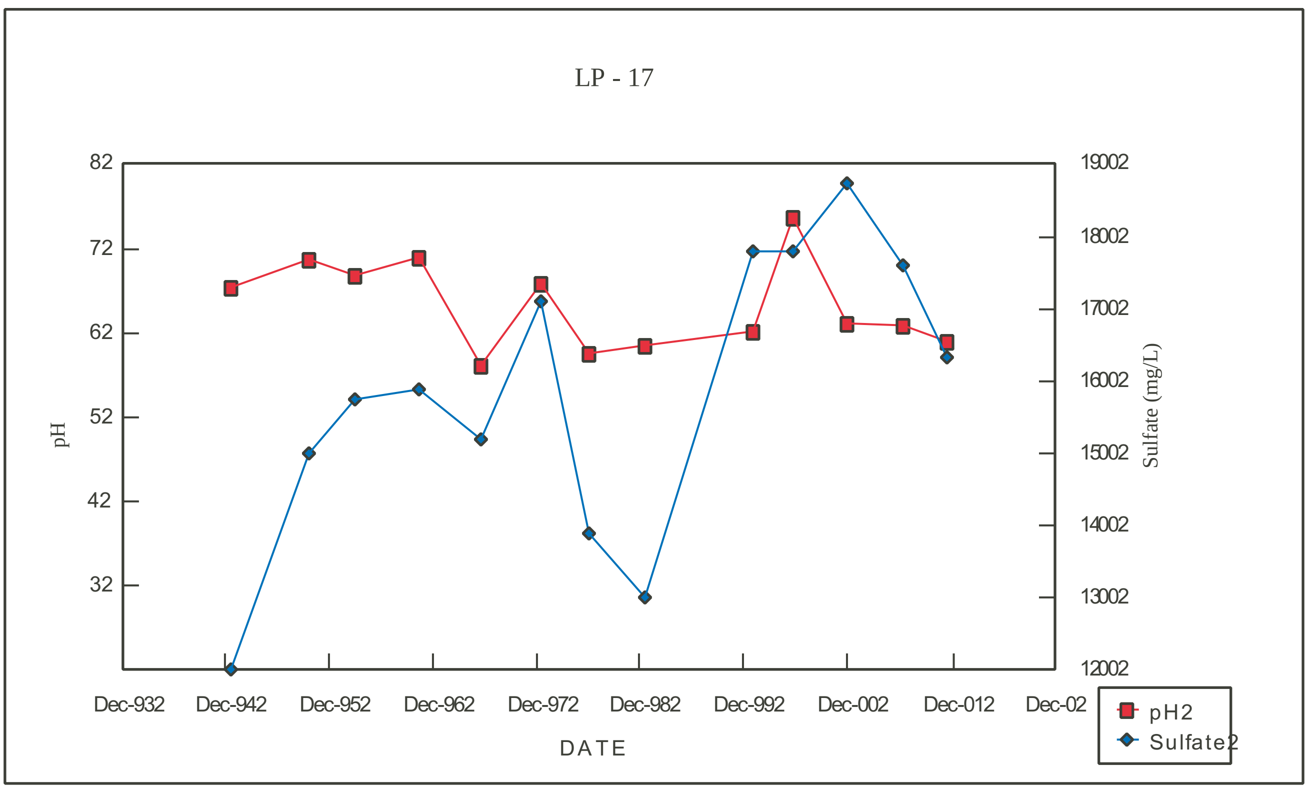


Figure 2-12. Sulfate concentrations for wells LP-14 and LP-17 near the Berkeley Pit.2

23,000 µg/L. All of the LP-series wells exceed the SMCL of 250 mg/L for sulfate except LP-10 (about 160 mg/L). Well LP-17 has the highest concentration with about 1,600 mg/L sulfate.

Section 2.1.3 Precipitation Plant Area Wells

Wells MR97-1, MR97-2, MR97-3, and MR97-4 (figure 2-7) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Water-level changes appear to correspond to water levels and/or flow in these ditches and ponds. This was especially apparent in the 1999-2000 water levels when MR began to make operational changes in leaching operations. As a result, the amount and level of water in collection ditches became less and was reflected in a drop of water levels in wells MR97-2 and MR97-3, which are adjacent to collection ditches (figures 2-13 and 2-14).

Variations in water levels occurred in well MR97-1 (figure 2-15) when MR began to discharge water from their Berkeley Pit copper recovery project into the pit using the historic HSB drainage channel. These variations are characterized by an initial increase in water levels followed by a gradual decline before leveling off. The channel, which is adjacent to well MR97-1, had been unused since April 1996, when HSB drainage water was captured and prevented from flowing into the pit.

Similar variations were observed in well MR97-1 during July 2001 and again in 2002, when a weir was installed (2001) and then relocated (2002) in the channel. The weir that was installed in 2001 was relocated upstream at the outlet of what was historically referred to in MR's precipitation plant operations as Pond 4. The weir was relocated as part of infrastructure changes relating to the HSB water treatment plant construction. The area occupied by Pond 4 was excavated and enlarged, then lined with lime rock during construction activities. Figure 2-16 shows the new weir installation and the lime rock along the pond sides. The weir's relocation resulted in a drop in water levels in well MR97-1, because the weir and the accompanying impounded water were moved upgradient of this well.

Water-level increases were also seen in wells MR97-2 and MR97-4 following MR's suspension of mining. After an initial rise in water levels, a gradual decline continued over the remainder of 2000 in these two wells. A similar increase was seen in well MR97-2 following the 2001 weir installation. Well

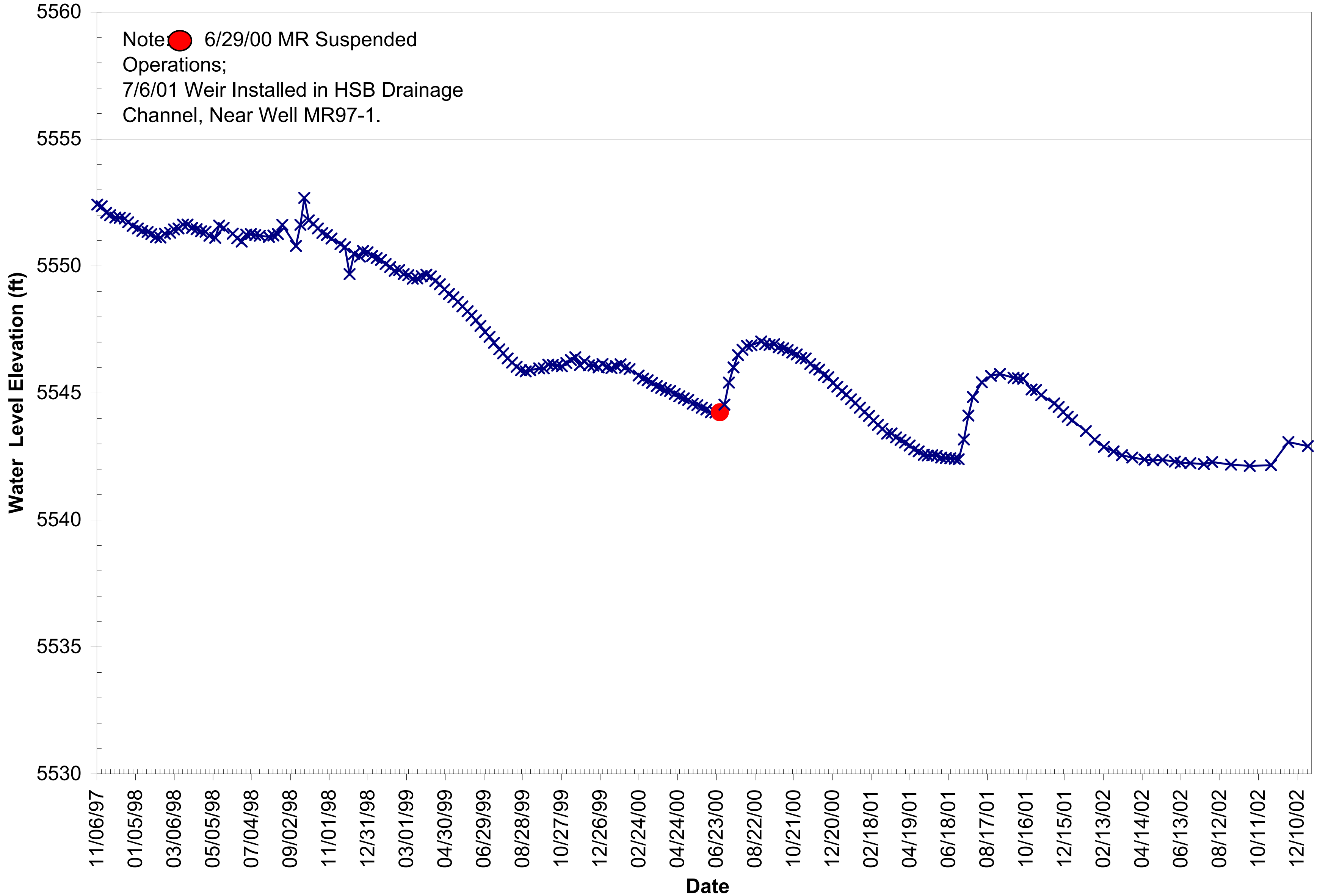


Figure 2-13. Water-level hydrograph for MR97-2 well.

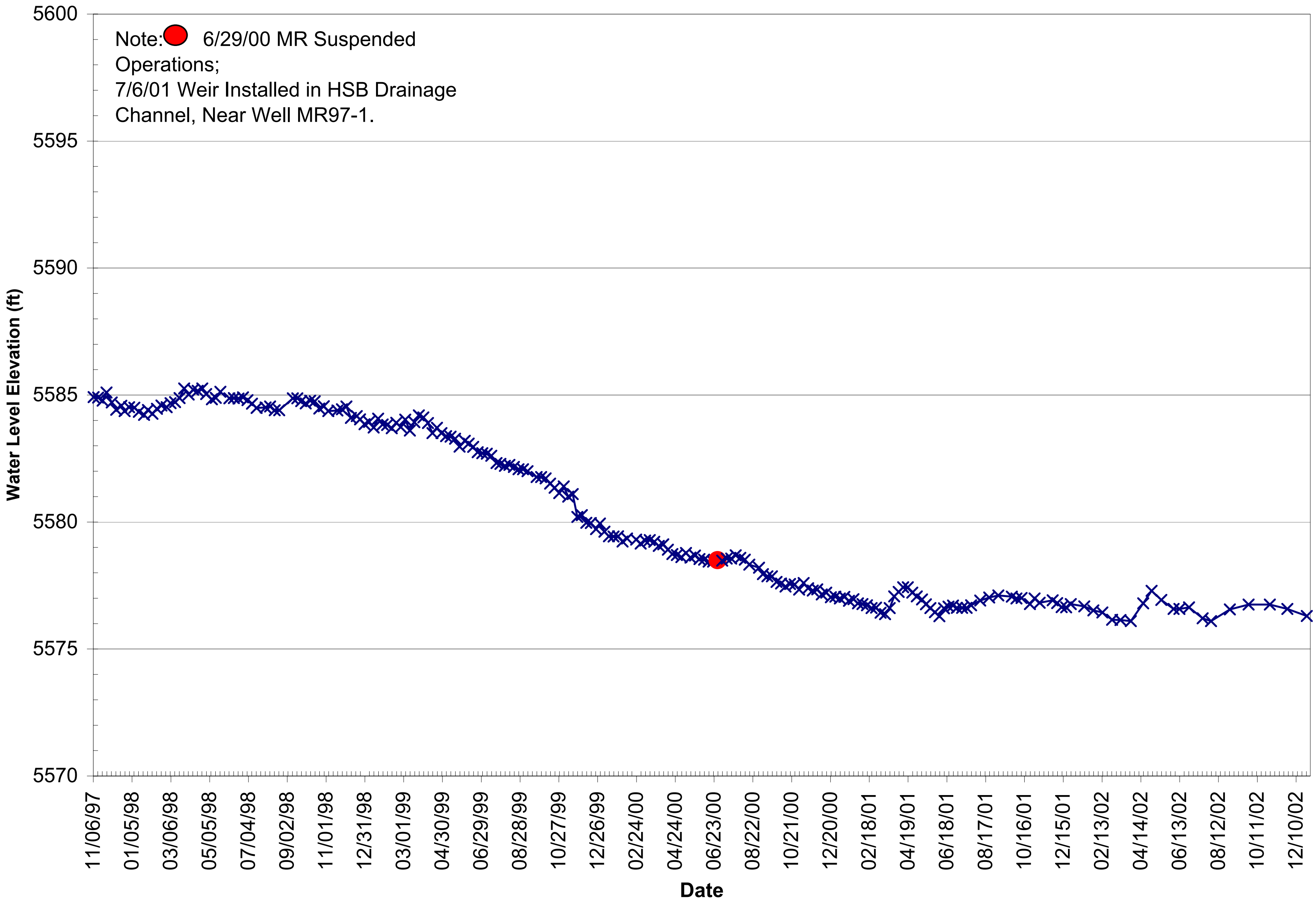


Figure 2-14. Water-level hydrograph for MR97-3 well.

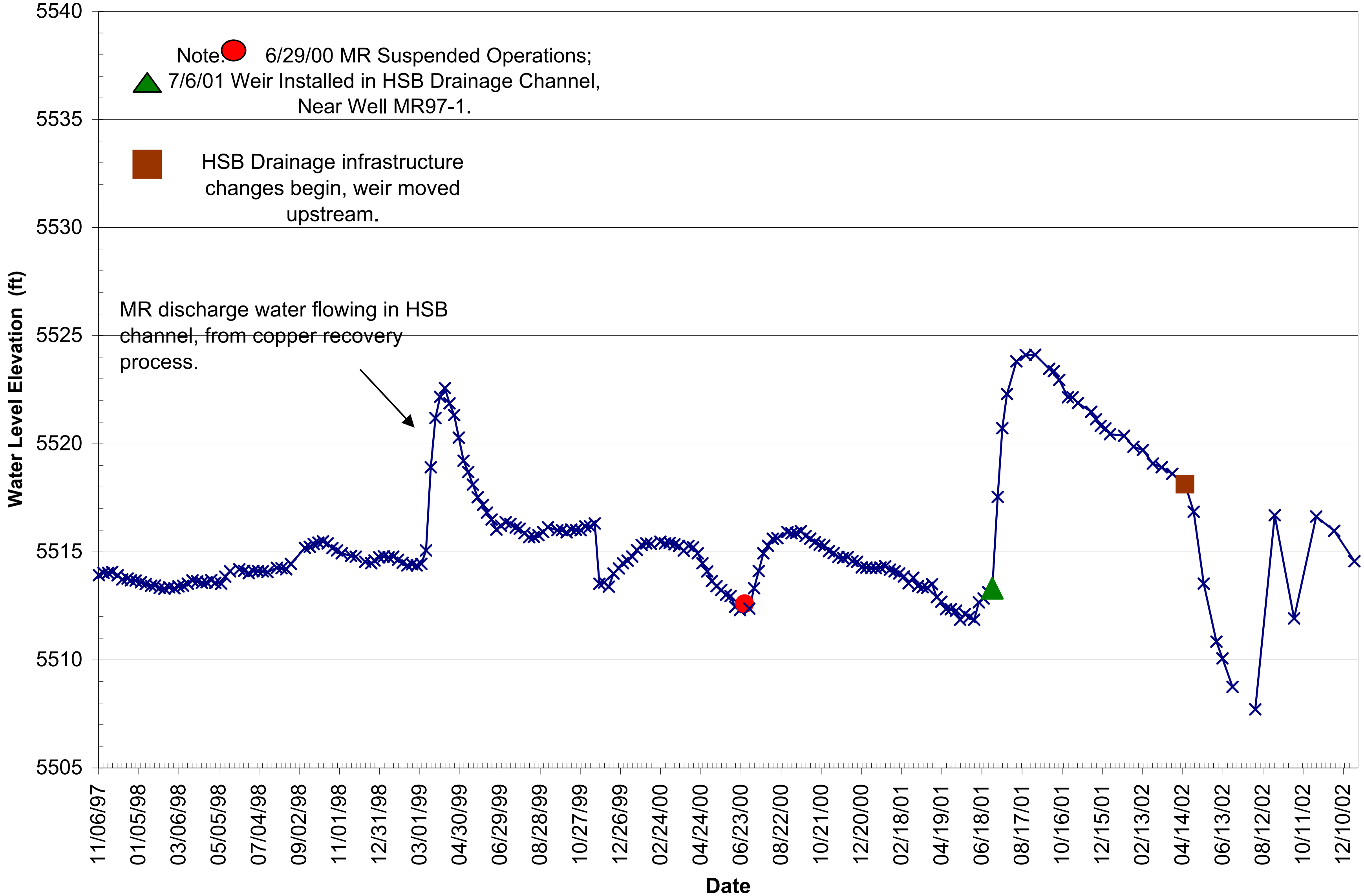


Figure 2-15. Water-level hydrograph for MR97-1 well.

Figure 2-16. Location of 2002 Horseshoe Bend Drainage weir installation (top) and expanded pond excavation (bottom).

operation of the leach pads and precipitation plant and associated facilities. Table 2.1.3.1 lists annual and net water-level changes for the four wells (MR97-1 through MR97-4).

The water level in well MR97-3 showed only a minor response to the 2002 construction activities. However, the overall trend continued to show a decline, which is most likely in response to the deactivation of the leach-pad operations. This conclusion is based upon the fact that this well is the closest to the leach pads and several collection ditches. It is also the MR-series well farthest away from the HSB drainage channel.

Table 2.1.3.1 Annual Water-Level Changes in MR97-Series Wells

Year	MR97-1	MR97-2	MR97-3	MR97-4
1997	-0.25	-0.84	-0.40	0.35
1998	1.07	-1.04	-0.67	2.20
1999	-0.27	-4.40	-3.91	0.02
2000	-0.20	-0.89	-2.88	-0.03
2001	6.17	-1.32	-0.29	0.78
2002	-5.88	-1.02	-0.47	1.60
Net Change	***0.64***	***-9.51***	***-8.62***	***4.92***

Water levels have declined more than 8 feet in the two wells nearest the leach pads and ancillary facilities since their installation in 1997 (table 2.1.3.1), while having a net increase in the two wells nearest the precipitation plant and HSB drainage channel. It appears there is a direct influence on the shallow alluvial aquifer in this area by mining operations. Changes in mine operations affect ground-water recharge in this area. Other changes, such as the weir installation and relocation, have affected ground-water levels in the area.

No water-quality samples were collected from this group of wells in 2001 or 2002. Previous sampling documented the presence of elevated metals in the area. This contamination is most likely the result of the leach pad and precipitation plant operations.

Section 2.1.4 GS-Series Wells

Continuous and monthly water-level monitoring of the six GS wells continued throughout 2002. The locations of these wells are shown on figure 2-17. Table 2.1.4.1 contains annual water-level changes for these wells. Wells GS-41, GS-44, and GS-46 are nested pairs. That is, the wells are drilled adjacent to each other, but they are drilled and completed at different depths. The S and D identify the shallow and deep wells in each nested pair. All six wells have had a net water-level decline since current monitoring began in 1993.

Figures 2-18 through 2-20 are water-level hydrographs with monthly precipitation totals shown for wells GS-41, GS-44, and GS-46. The seasonal variations in water levels closely follow monthly precipitation trends. Water-levels begin a gradual increase in the spring as precipitation increases. There is a two- to three-month lag (delay) between peak rainfall and peak water levels.

Table 2.1.4.1 Annual Water-Level Changes in GS-Series Wells

Year	GS-41S	GS-41D	GS-44S	GS-44D	GS-46S	GS-46D
1993	0.76	0.78	0.62	0.66	0.80	0.78
1994	0.20	0.23	0.00	0.00	0.18	0.24
1995	1.35	1.29	1.32	1.26	1.38	1.30
1996	0.59	1.65	1.12	0.89	0.98	1.20
1997	1.32	0.20	0.58	0.79	1.09	1.18
1998	-0.18	-0.06	0.09	0.07	1.17	0.24
1999	-1.41	-1.49	-1.28	-1.25	-2.41	-1.65
2000	-1.91	-1.78	-1.51	-1.39	-1.21	-2.07
2001	-0.28	-0.41	-0.22	-0.38	-1.78	-0.92
2002	-0.82	-0.81	-0.94	-0.82	-1.18	-1.18
Net Change	***-0.38***	***-0.40***	***-0.22***	***-017***	***-0.84***	***-0.88***

Water-level changes in wells GS-41S and GS-41D were similar once again during 2002 (figure 2-18) and the influence of precipitation was very noticeable. Water levels declined more than 0.8 foot in these two wells during 2002 — almost twice that of 2001. The overall downward trend seen following the 1998 Berkeley Pit landslide continued.

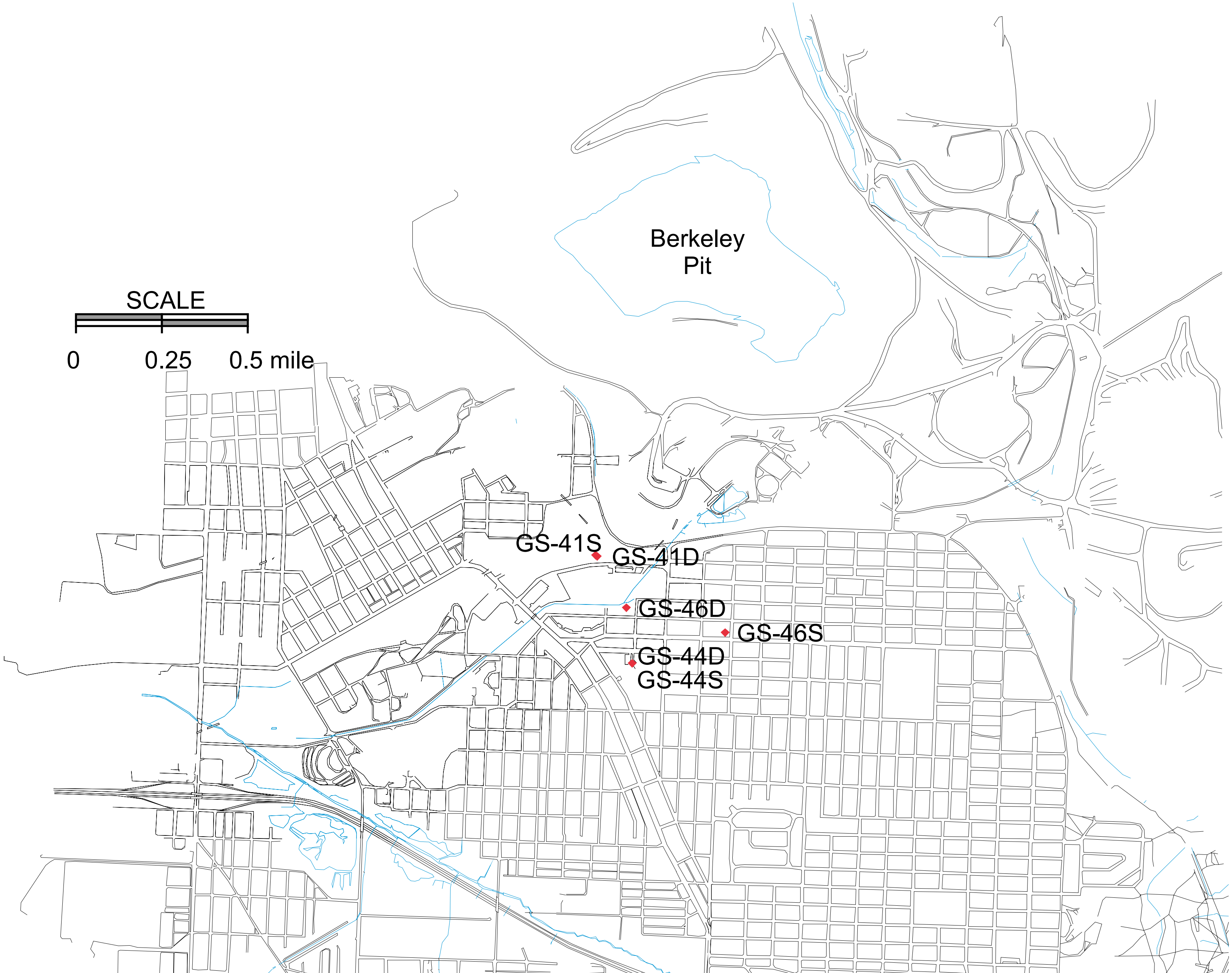


Figure 2-17. GS Wells Location Map.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

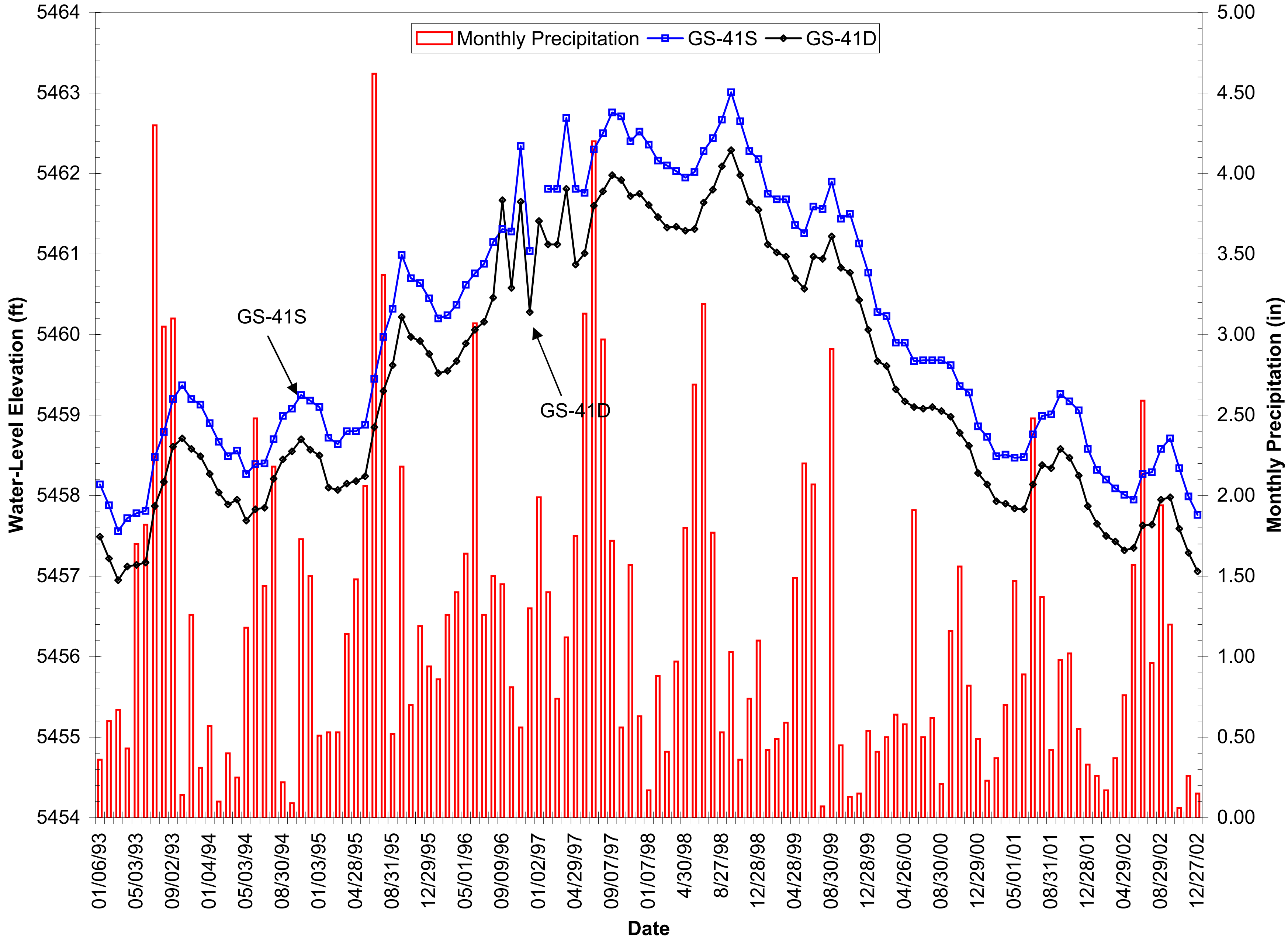


Figure 2-18. Water-level hydrographs for GS-41S and GS-41D wells.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

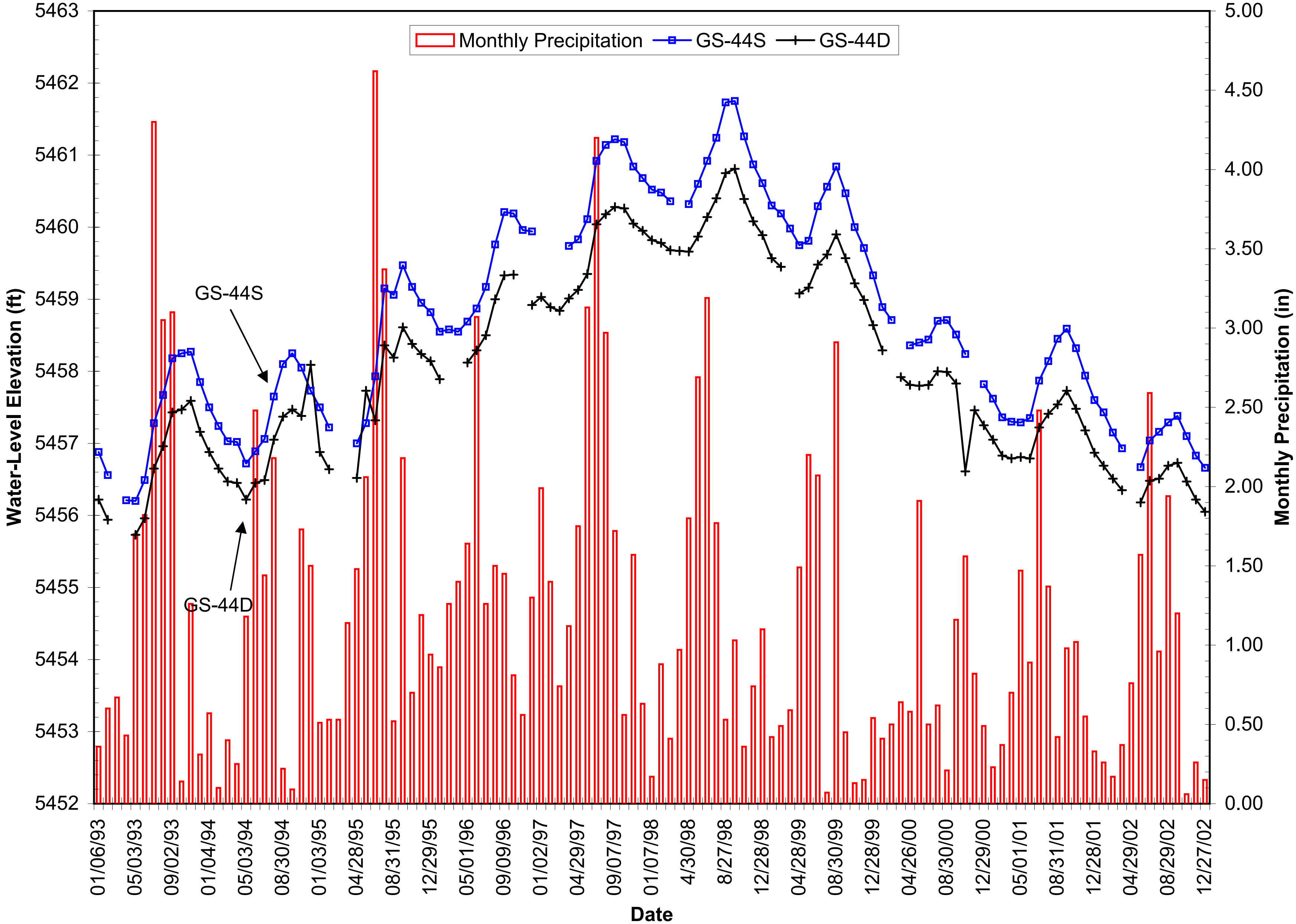


Figure 2-19. Water-level hydrographs for GS-44S and GS-44D wells.

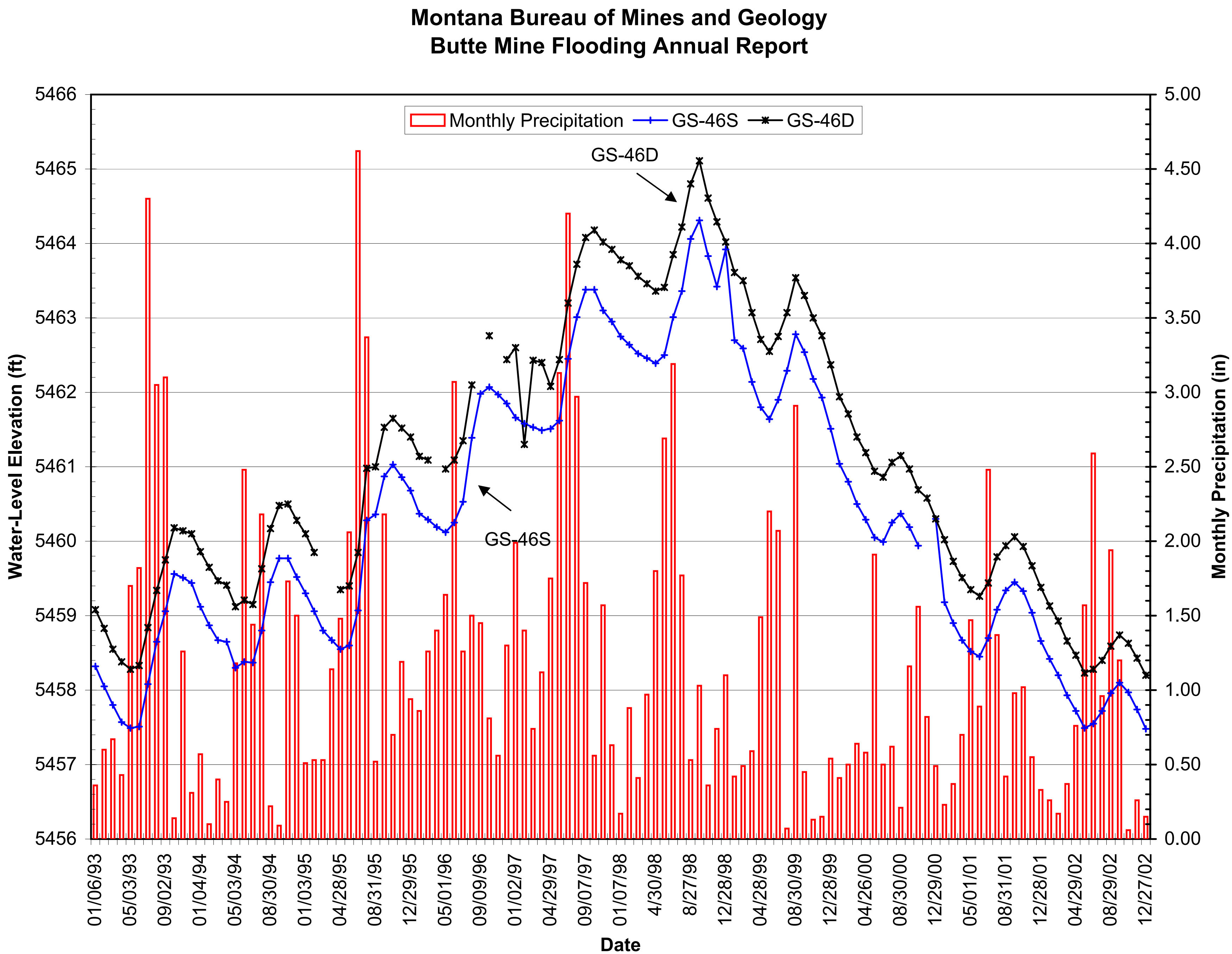


Figure 2-20. Water-level hydrographs for GS-46S and GS-46D wells.

Wells GS-44S and GS-44D had similar water-level changes throughout 2002 (figure 2-19). The rise and fall of seasonal water levels are similar to those described for wells GS-41S and 41D. The water levels also had a greater level of decline for the year than seen in 2001, with the net 2002 change being more than 0.8 foot.

Overall, water-level trends were similar during 2001 in wells GS-46S and GS-46D (figure 2-20), and followed the trends discussed previously for wells GS-41 and GS-44. Water-levels declined 1.18 feet in both wells during 2002. These declines are greater than those in the other two pairs of wells. The seasonal trends are the same as those in the other GS-series wells.

In both the GS-41 and GS-44 wells, the water levels in the shallow wells are higher than those of the deeper wells, implying that there is a downward vertical gradient. That is, water in the upper part of the alluvial aquifer is moving down, providing recharge to the lower portions of the aquifer. Water levels in wells GS-46S and GS-46D show the opposite. The water level in well GS-46D is higher than the water level in GS-46S. This implies that water had the potential to move upwards in the aquifer and possibly discharge into a surface-water body, such as Silver Bow Creek.

No water-quality samples were collected from these wells as part of the 2002 BMFOU monitoring. Therefore, no discussion of water quality is included with this year's report.

Section 2.1.5 Domestic Well Monitoring

Monitoring continued in 13 domestic wells for the 6th year. However, monitoring of these wells was discontinued after July 2002. Monitoring of the domestic wells was dropped in the CD, to be replaced by four new dedicated alluvial wells. The new wells should be installed during 2003. The locations of the domestic wells are shown on figure 2-21. Table 2.1.5.1 contains summary water-level data for these wells.

Water-level changes were a foot or more in a number of wells, while others had changes less than a foot during 2002. Five of the seven wells east of Harrison Avenue exhibited a similar decrease in water levels for 2002. The size of the water-level drop, while less than last year's, is greater than that seen in most of the previous years. It is possible that these wells reflect the cyclical nature of water levels due to short-term climatic conditions. The Butte Basin had above-average precipitation between 1993 and 1998, which has been followed by a period of below-average precipitation.

Figures 2-22 and 2-23 are hydrographs of selected domestic monitoring wells east of Harrison Avenue. The effect of precipitation was less pronounced in wells 93-20, 93-22, 93-25, and 93-26 (figures 2-22 and 2-23) than in previous years. However, it is possible that if monitoring had continued throughout the remainder of the year, the influence of precipitation would have been similar to that of

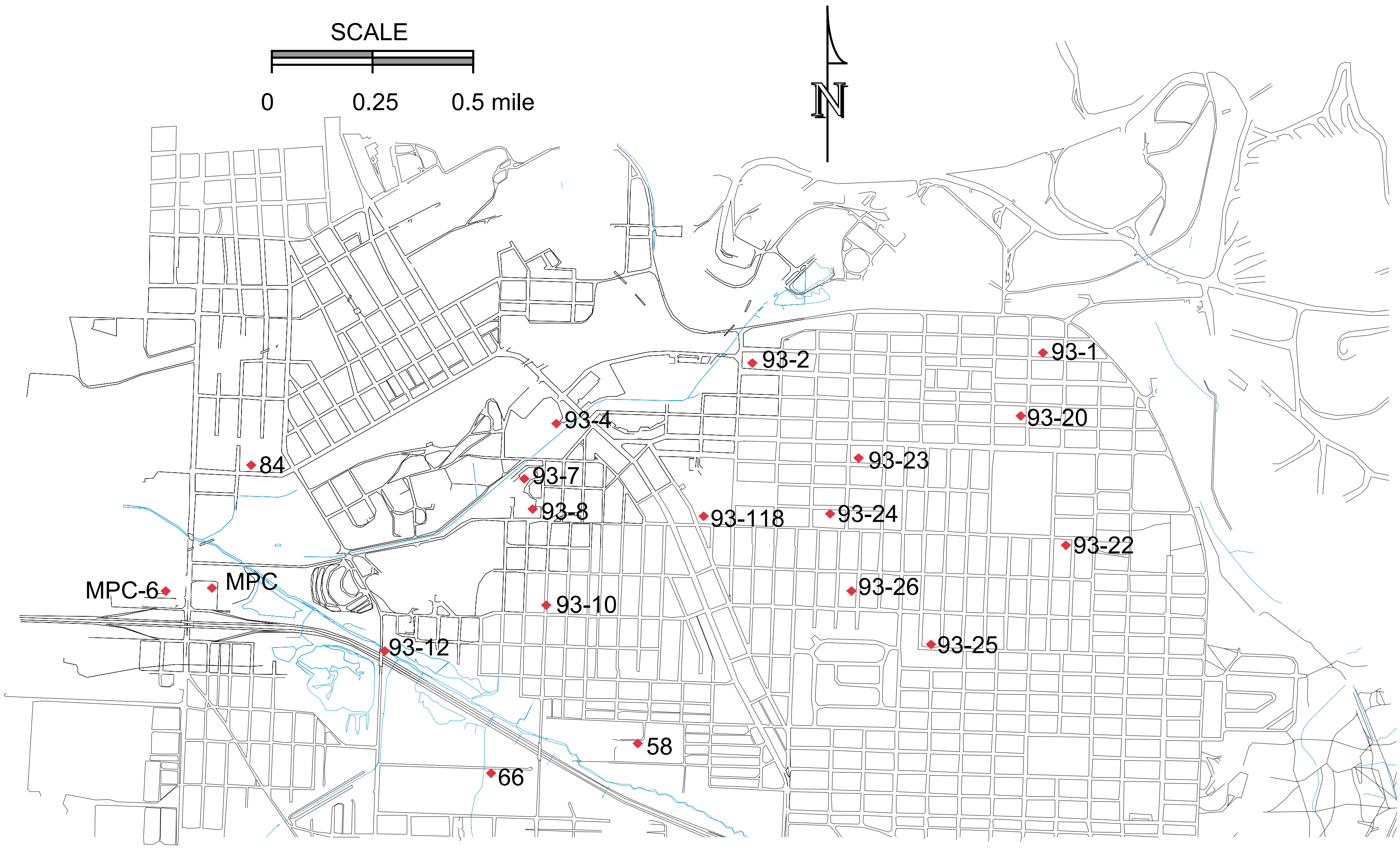


Figure 2-21. Domestic Well Location Map.

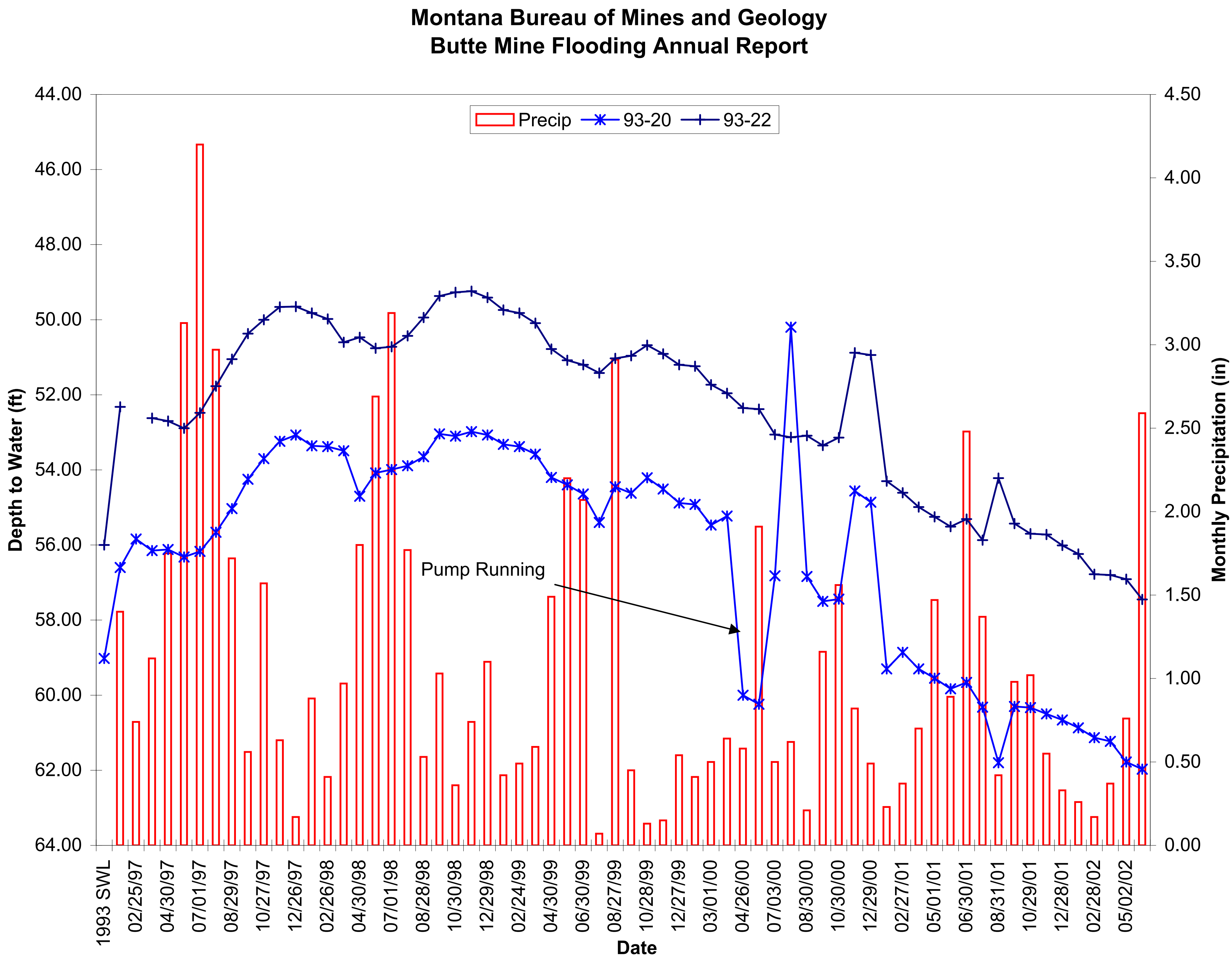


Figure 2-22. Water-level hydrographs for domestic wells 93-20 and 93-22.

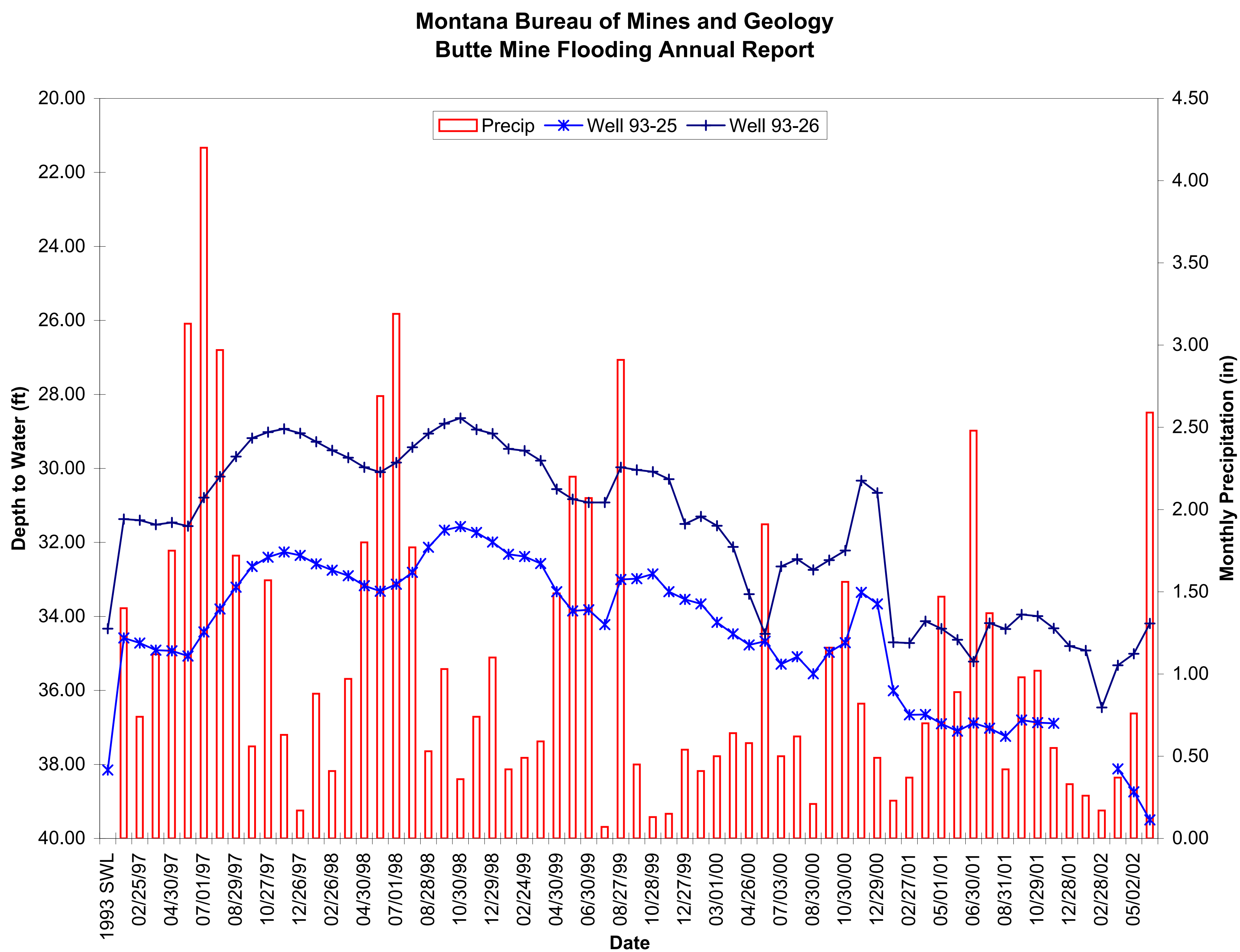


Figure 2-23. Water-level hydrographs for domestic wells 93-25 and 93-26.

Table 2.1.5.1 Annual Water-Level Changes and Total Changes for Domestic Wells

Map Well ID	WL Change (ft) 1993-12/1997	WL Change (ft) 1998	WL Change (ft) 1999	WL Change (ft) 2000	WL Change (ft) 2001	WL Change (ft) 2002	TOTAL WL CHANGE (ft)
93-20	5.95	0.00	-1.81	0.02	-5.80	-1.31	-2.95
93-22	6.35	0.24	-1.79	0.26	-5.07	-1.44	-1.45
93-25	5.80	0.36	-1.55	-0.12	-3.23	-2.61	-1.35
93-26	5.28	-0.01	-2.44	0.84	-4.14	0.61	0.14
93-23	4.88	-0.06	-1.96	0.70	-4.65	-1.30	-2.39
93-24	5.37	0.04	-1.65	-22.56*	18.99	1.04	1.23
93-2	3.45	1.14	-2.43	-0.04	-2.07	-0.79	-0.74
93-118	1.66	---	---	---	---	---	1.66
93-4	0.58	0.01	-0.03	-0.01	-0.62	---	-0.07
93-7	-0.04	-0.11	-0.41	-0.46	-0.25	-0.09	-1.36
93-8	-0.35	-0.05	-0.43	-0.49	-0.14	-0.15	-1.61
93-9	-1.08	-0.03	-0.34	0.17	-0.73	0.15	-1.86
93-10	-0.21	0.04	-0.48	0.37	-0.31	0.38	-0.95
93-12	1.58	-5.02	4.74	-0.06	-0.08	-1.77	-3.77
MPC	-0.07	0.14	-0.13	-0.04	-0.14	0.01	-0.23

* December water level measured while pump was operating.

— water level not measured.

previous years. Water levels usually stop their decline in the spring, one to two months after precipitation increases, before leveling off and falling during the winter. Water-level trends are very similar in each of these figures.

Figures 2-24 and 2-25 are hydrographs of selected domestic monitoring wells (93-4, 93-7, 93-8, 93-9, 93-10, and 93-12) west of Harrison Avenue. The seasonal trends are similar to the other alluvial water levels. Water levels declined in three of the six wells during 2002.

Total water-level changes in the entire group of domestic wells range from a decline of 3.77 feet to a rise of 1.23 feet, at wells 93-12 and 93-24, respectively. The seasonal water-level changes are remarkably similar to those seen in other alluvial monitoring wells. Minimum water levels occur in early spring and maximum water levels occur in the late summer or early fall. No effects of the September 1998 Berkeley Pit landslide were seen in any of the domestic wells.

Based upon the 6 years of data there are several things apparent from these figures. There is a delay (lag) period between precipitation increases and well responses south of the pit and east of Harrison Avenue. This is similar to trends seen in the GS-series wells. Water-level response to increased precipitation in wells west of Harrison Avenue is nearly immediate. Increases in water levels are seen in the same month precipitation levels increase, or the following month, and are short lived, with levels dropping the next month if precipitation levels decrease.

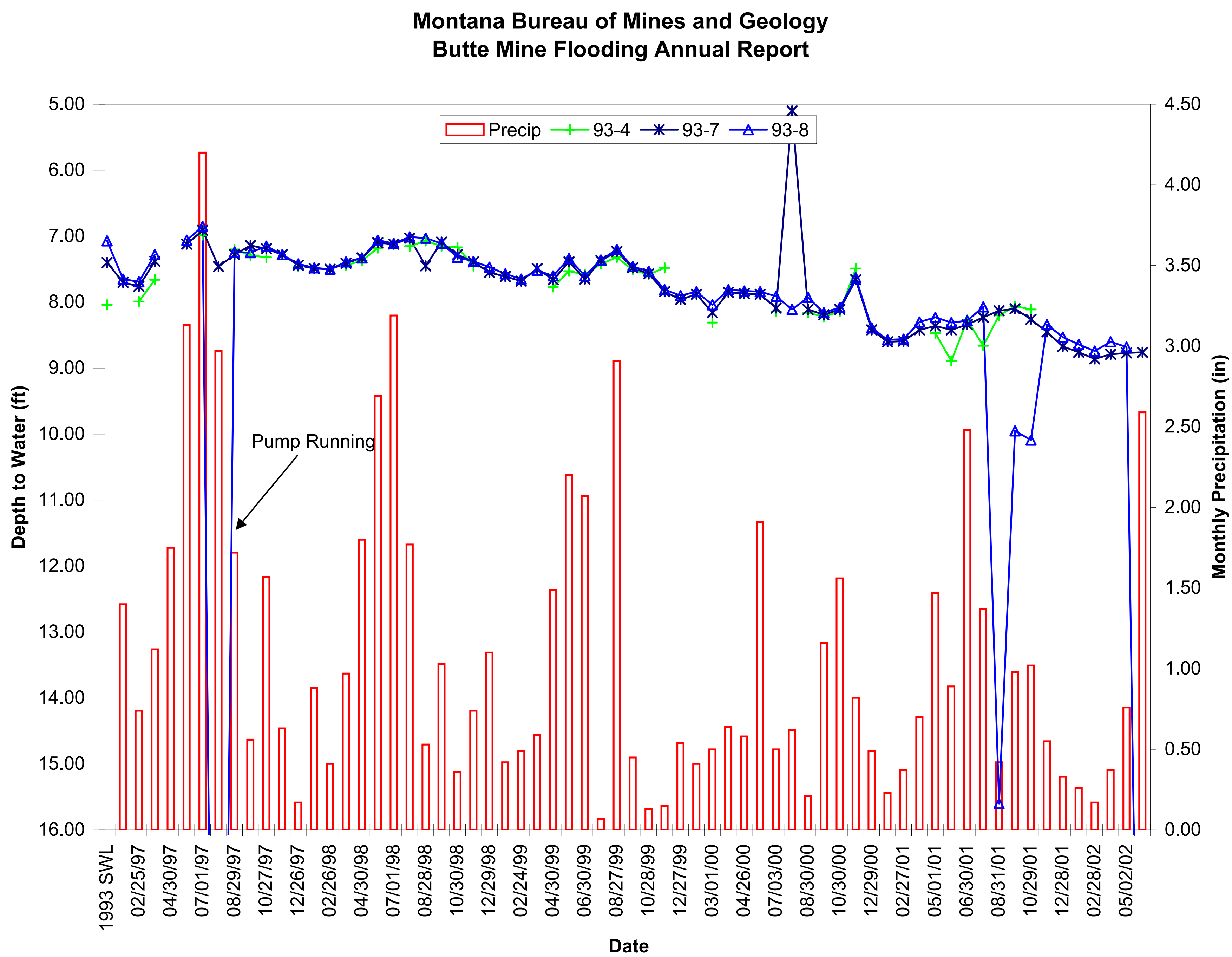


Figure 2-24. Water-level hydrographs for domestic wells 93-4, 93-7 and 93-8.

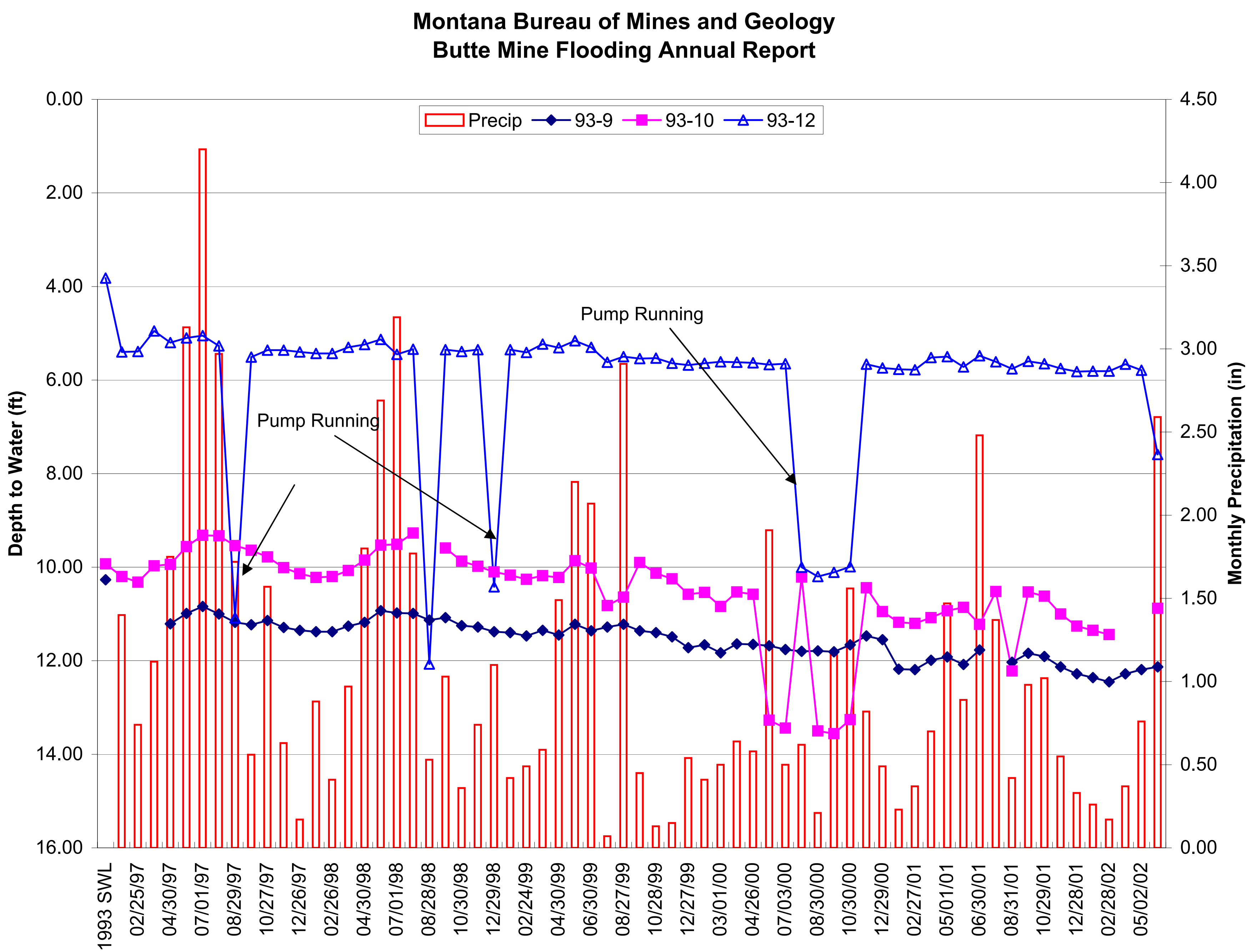


Figure 2-25. Water-level hydrographs for domestic wells 93-9, 93-10, and 93-12.

No water-quality samples were collected from these wells during 2002. These wells were used solely for water-level monitoring.

Section 2.2 East Camp Underground Mines

Monitoring of water levels in the seven East Camp underground mines continued. Their locations are shown on figure 2-26. During the year 2002, water levels rose between 11 and 14 feet in the mines, which is four to five feet less than last year. The Berkeley Pit water level rose 15.56 feet, or about 2.5 feet less than last year (Table 2.2.1). Figure 2-27 shows the annual water level changes graphically for these sites.

Figure 2-28 is a hydrograph based upon water levels for the Anselmo Mine and Kelley Mine. There are no obvious variations in water levels on this figure; however, when water levels are plotted from 1995 through 2002, several changes are noticeable (figure 2-29). The stoppage of HSB drainage water from entering the pit in 1996 resulted in a flattening of the line, while the 2000 addition of this same water resulted in an increased slope of the line. The large water-level change (rise) following the 1998 Berkeley Pit landslide is very noticeable.

Figure 2-30 shows monthly water-level changes in the Berkeley Pit through 2002. The continued addition of HSB drainage water into the pit is responsible for the increased rate of rise. Water-level changes seen over the last 6 months of 2000, following the addition of HSB drainage water, continued through 2002. A similar trend was seen in all the East Camp underground mines. Water levels remain the highest in the sites farthest from the Berkeley Pit. This continues to confirm that water is flowing towards the pit, thus keeping the pit the low point in this system.

Last year it was noted that the Kelley Mine monthly and annual water-level rise was considerably less than that of the other mines. The annual rise was about 5 feet less than the other East Camp mines. It was speculated that the close proximity between the mine and Berkeley Pit, and the potentially greater level of interconnection between the two sites was responsible for this change. However, the 2002 water-level changes in the Kelly Mine were similar to those of the other mines. Therefore, the reasons behind the 2001 differences remain unknown. Based upon the volume estimates of the underground mines and water-level elevations, over 85 percent of the underground mine workings are flooded.

Figure 2-31 is a plot of selected mine-shaft water levels versus precipitation. There is no apparent influence on water levels in the underground mines from monthly precipitation. It is obvious that the rise in water levels is a function of historic mine-dewatering activities and the void areas in the underground mines and Berkeley Pit, and is not a function of precipitation.

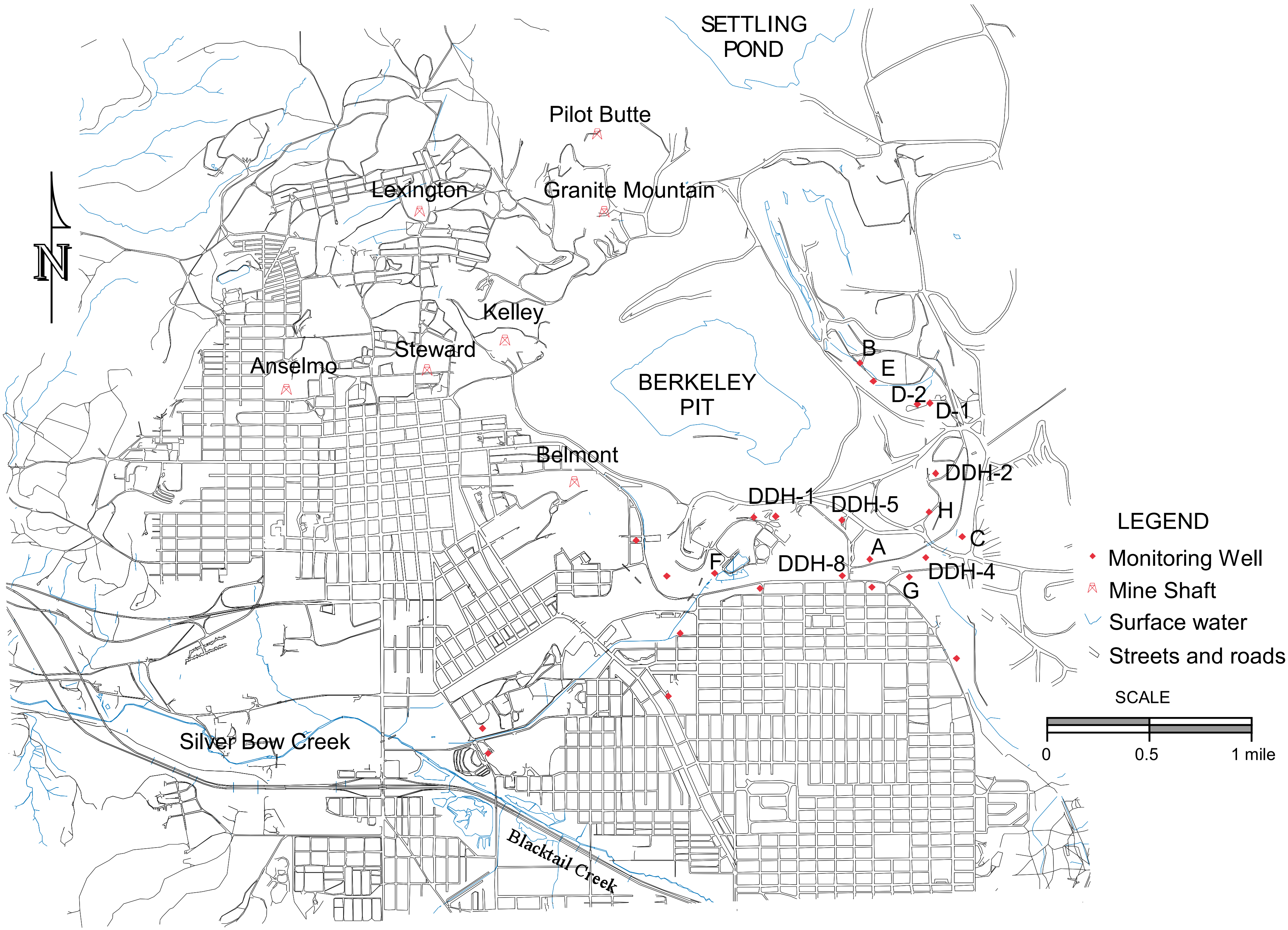


Figure 2-26. East Camp mines and Bedrock Wells Location Map.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

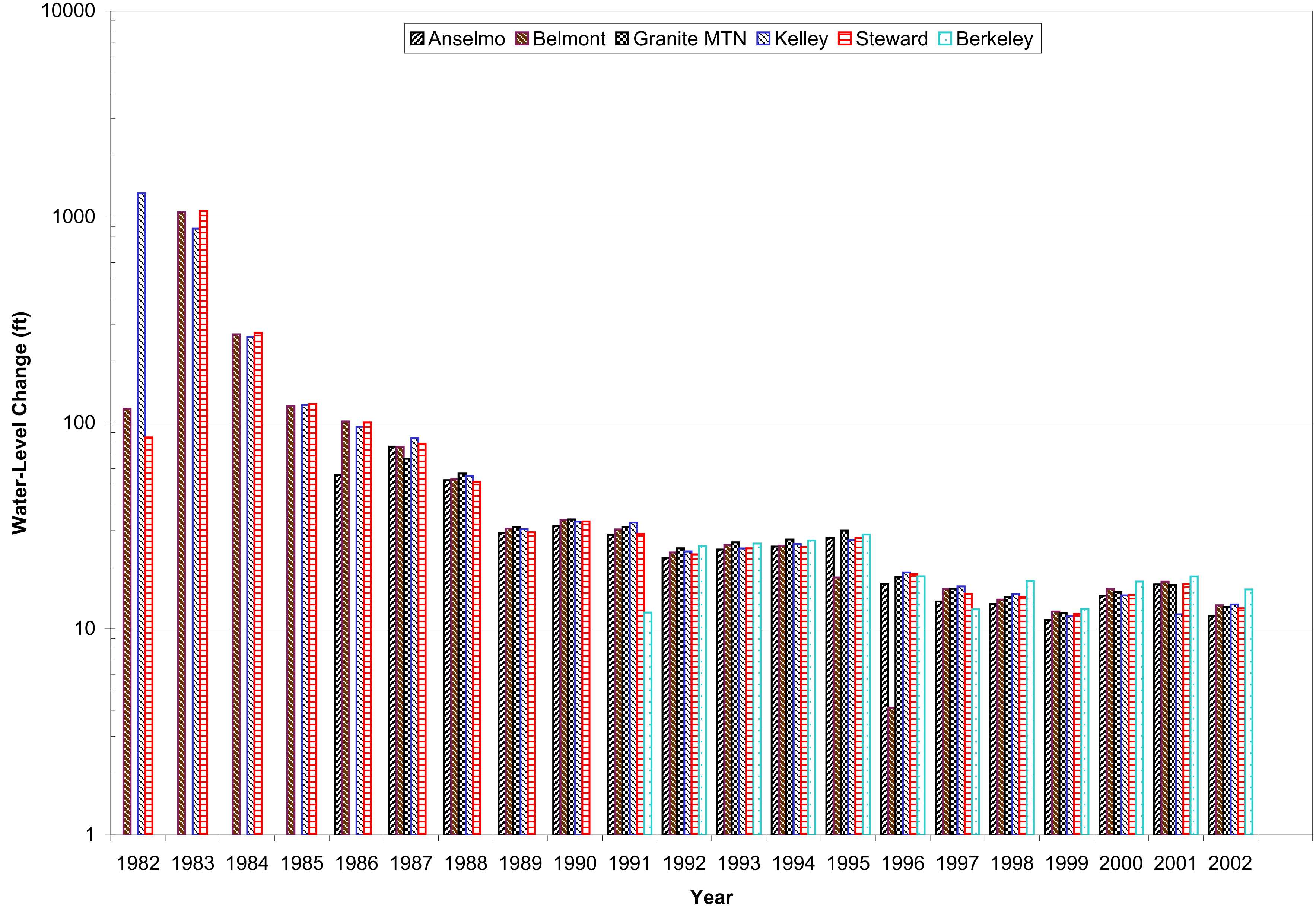


Figure 2-27. East Camp mines annual water-level changes.

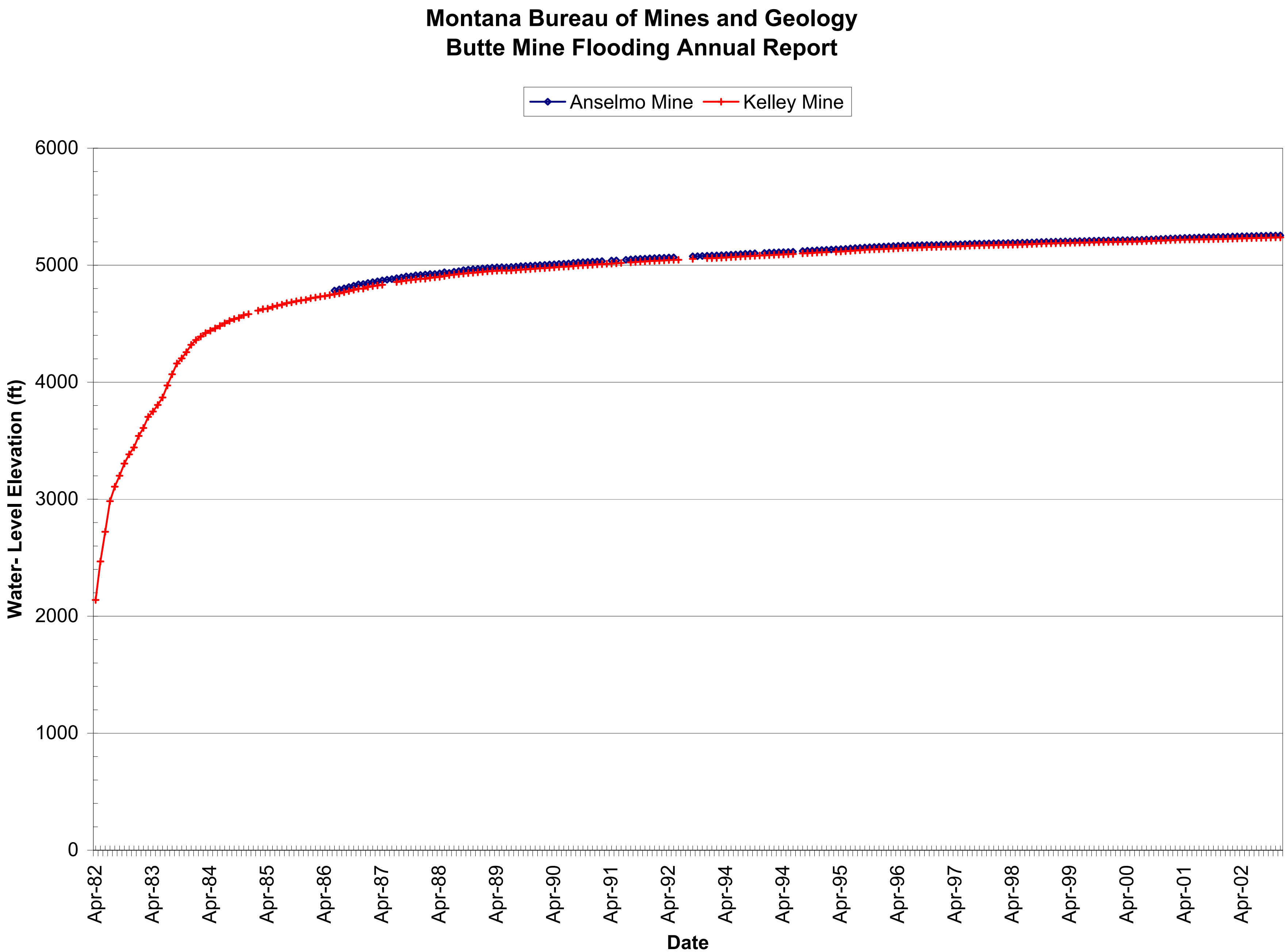


Figure 2-28. Water-level hydrographs for the Anselmo Mine and Kelley Mine.

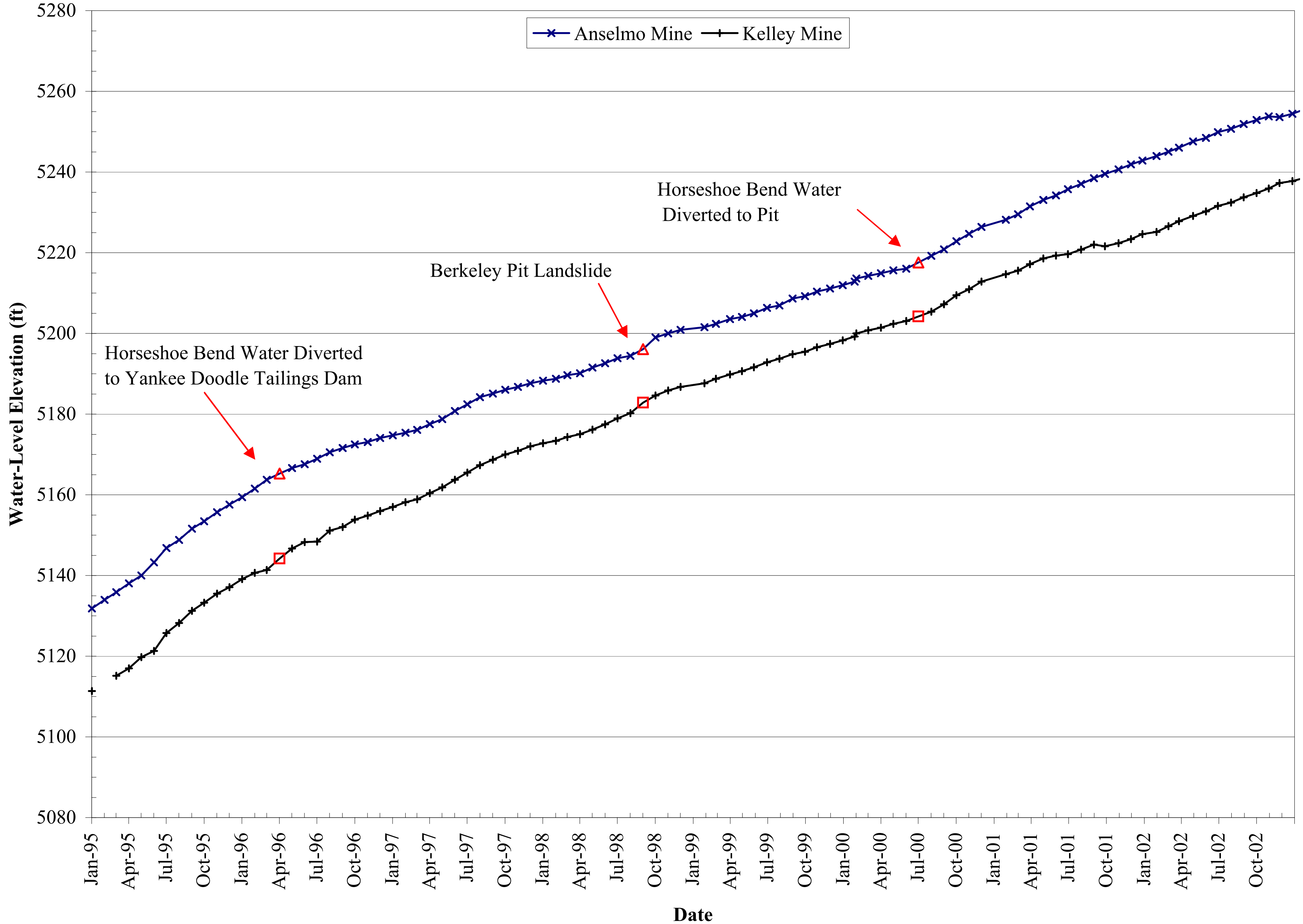


Figure 2-29. Water-level hydrograph, 1995-2002, Anselmo Mine and Kelley Mine.

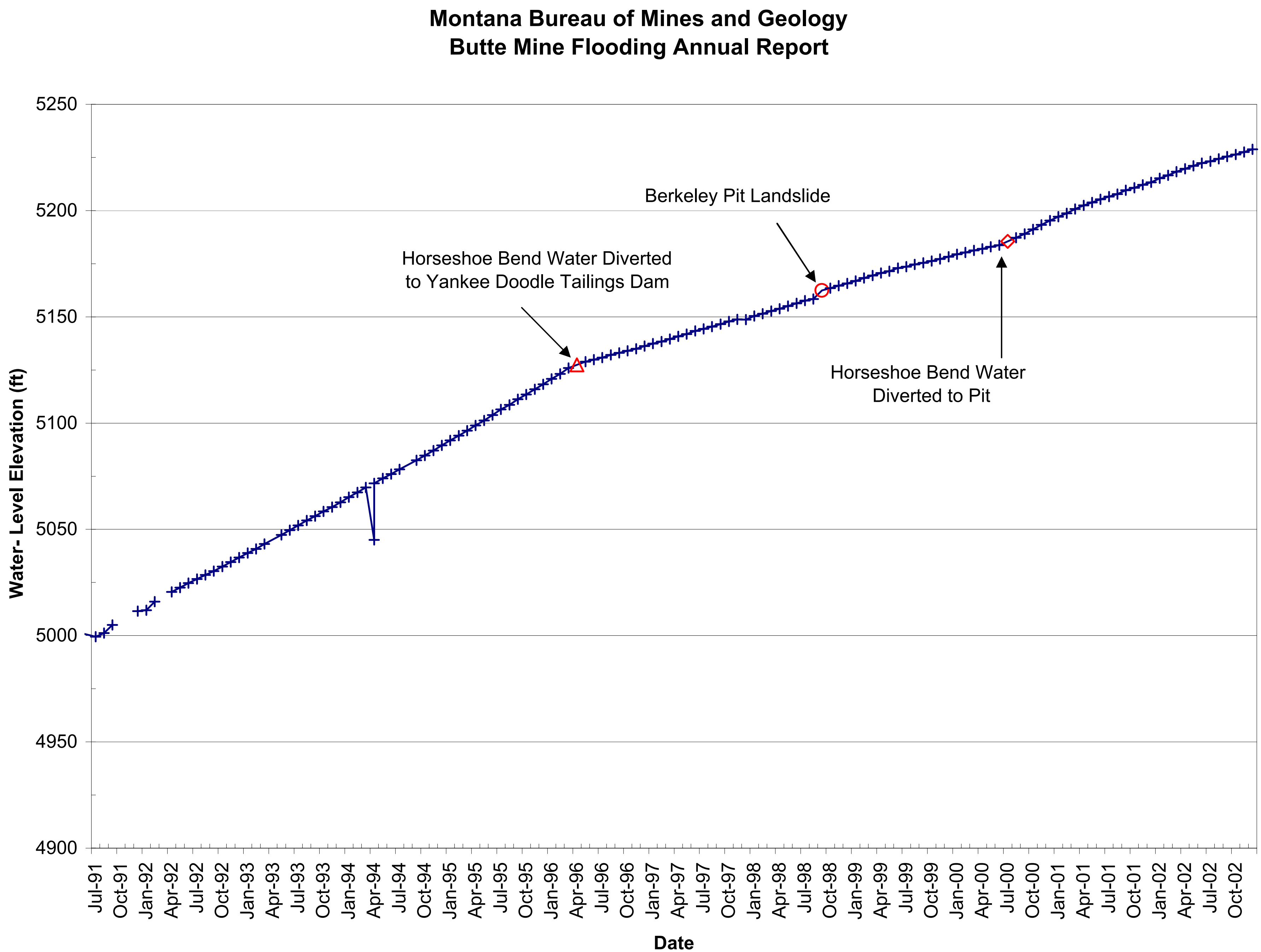


Figure 2-30. Water-level hydrograph for the Berkeley Pit.

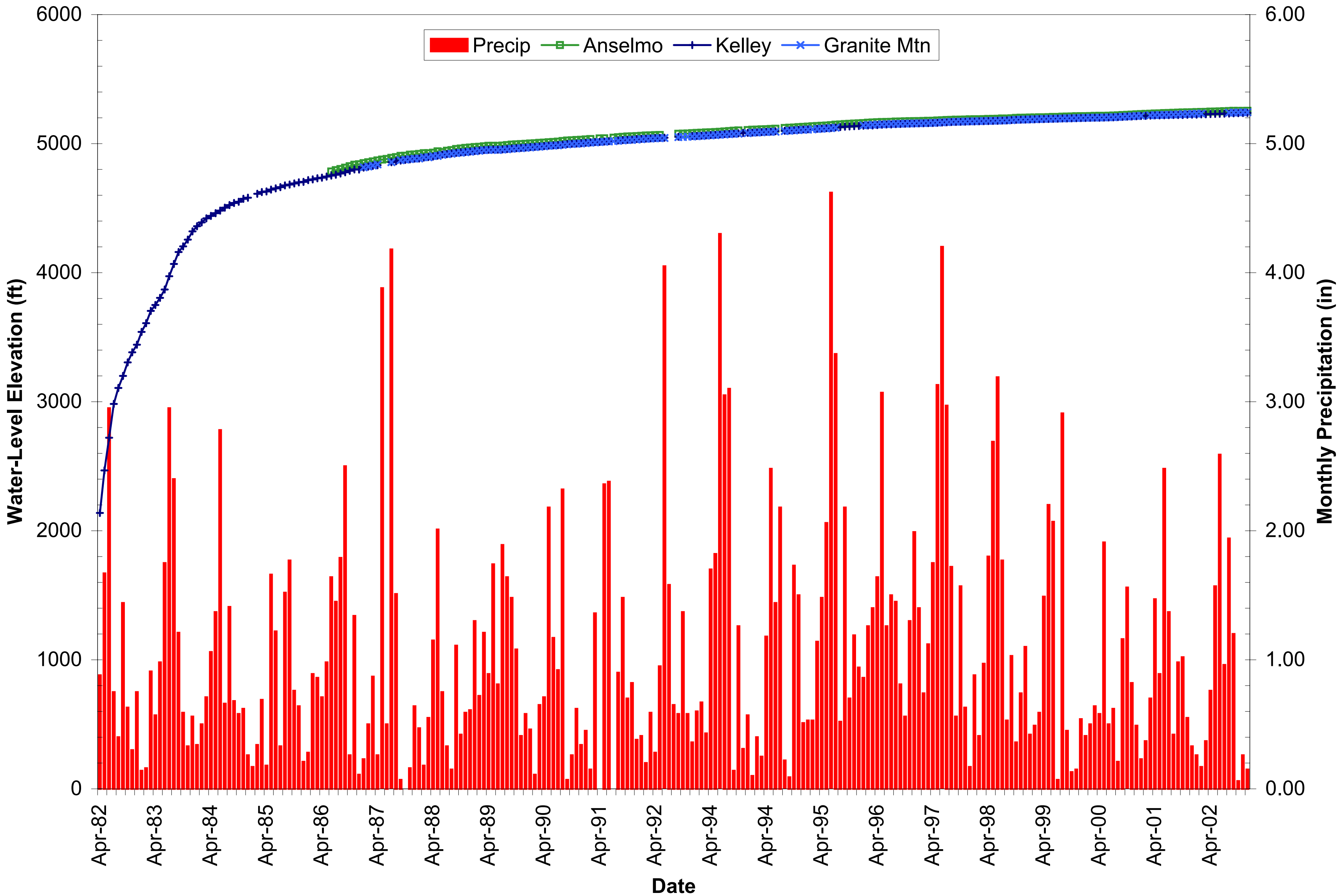


Figure 2-31. Water-level hydrographs for selected East Camp Mines, with monthly precipitation.

Table 2.2.1 Annual Water-Level Changes in East Camp Mines, in feet

Year	Berkeley	Anselmo	Kelley	Belmont (1)	Steward	Granite	Lexington	Pilot
1982			1,304.00	117.00	85.00			
1983			877.00	1,054.00	1,070.00			
1984			262.00	269.00	274.00			
1985			122.00	121.00	123.00			
1986		56.00	96.00	102.00	101.00			
1987		77.00	84.00	77.00	79.00	67.00		
1988		53.00	56.00	53.00	52.00	57.00	8.10	
1989		29.00	31.00	31.00	29.00	31.00		
1990		32.00	33.00	34.00	33.00	34.00		
1991	12.00	29.00	33.00	30.00	29.00	31.00		
10- Year Change	***12.00***	***276.00***	***2,898.00***	***1,888.00***	***1,875.00***	***220.00***	***8.10***	
1992	25.00	22.00	24.00	24.00	23.00	25.00		
1993	26.00	24.00	25.00	26.00	25.00	26.00		
1994	27.00	25.00	26.00	25.00	25.00	27.00		
1995	29.00	28.00	27.00	18.00	28.00	30.00		
1996	18.00	16.00	19.00	4.15	18.00	18.00	1.19	3.07
1997	12.00	13.58	16.09	15.62	14.80	15.68	12.79	18.12
1998	17.08	13.23	14.73	13.89	14.33	14.24	13.71	11.26
1999	12.53	11.07	11.52	12.15	11.82	11.89	10.65	11.61
2000	16.97	14.48	14.55	15.66	14.60	15.09	14.01	14.11
2001	17.97	16.43	11.77	16.96	16.48	16.35	15.95	16.59
2002	15.56	11.60	13.15	13.02	12.60	12.82	12.08	11.33
Grand Total Change*	***229.30***	***470.65***	***3,099.26***	***2,071.16***	***2,078.77***	***432.04***	***88.48***	***86.09***

(1) Mine shaft collapsed in 1995; a replacement well was drilled adjacent to the mine, into mine workings, in 1997. Since the well was drilled into the Belmont Mine workings it is assumed that this water level is reflective of the Belmont Mine.
(*)Total change is the measured change in water level. Access or obstructions have prevented continuous water-level measurements at some sites.

Section 2.2.0.1 Water Quality

Water quality in the East Camp mines has been steady or slightly improving over the last few years. Data collected in 2002, however, suggest a significant departure from previous trends. Data from several shafts indicate large changes in concentrations of chemical constituents in the water. Such a departure from recent trends may be indicative of problems with the laboratory analysis or with sample collection. Duplicate samples analyzed by separate labs produced similar results; no analytical error was indicated. Sample collection methods, however, may have had an effect on the results. As noted in a previous annual report (Metesh and Duaime, 2001), all of the shafts exhibit a chemocline at a depth of from 50 to 100 feet. In recent years, samples have been collected from a fixed depth from the shaft collar rather than a fixed depth from the water surface. With an annual rise of 12 to 20 feet, only a few years are required to change the sample depth enough to cross the chemocline. Sample methods are under review and will likely be changed to represent a depth related to the water surface.

The Kelley Mine has exhibited high concentrations and large variations of arsenic over the period of record. There has been a trend toward decreasing concentrations of copper and increasing concentrations of arsenic for the past few years. The trend in copper concentration continues to decrease slightly, but arsenic increased from 5,780 µg/L in 2001 to 13,400 µg/L in 2002 (figure 2-32). The last sample from the Kelley had one of the lowest concentrations of copper and the highest arsenic concentration over the period of record. Similarly, sulfate increased from about 2,800 mg/L to about 8,000 mg/L and iron increased from 460 to almost 2,100 mg/L (figure 2-33). Large increases in concentrations were also reported for iron, manganese, magnesium, zinc, and nickel.

Similar changes in concentrations are evident in Anselmo Mine, but most fall within the trend of recent years. Data collected in 2002 show notable increases in concentrations of several dissolved constituents including arsenic (figure 2-34), aluminum, iron, and manganese, but decreasing concentrations of copper and zinc. The concentration of sulfate has remained relatively consistent near 1,000 mg/L throughout the period of record (figure 2-34). A summary of selected analytes for the East Camp monitoring sites is presented in table 2.2.0.1.

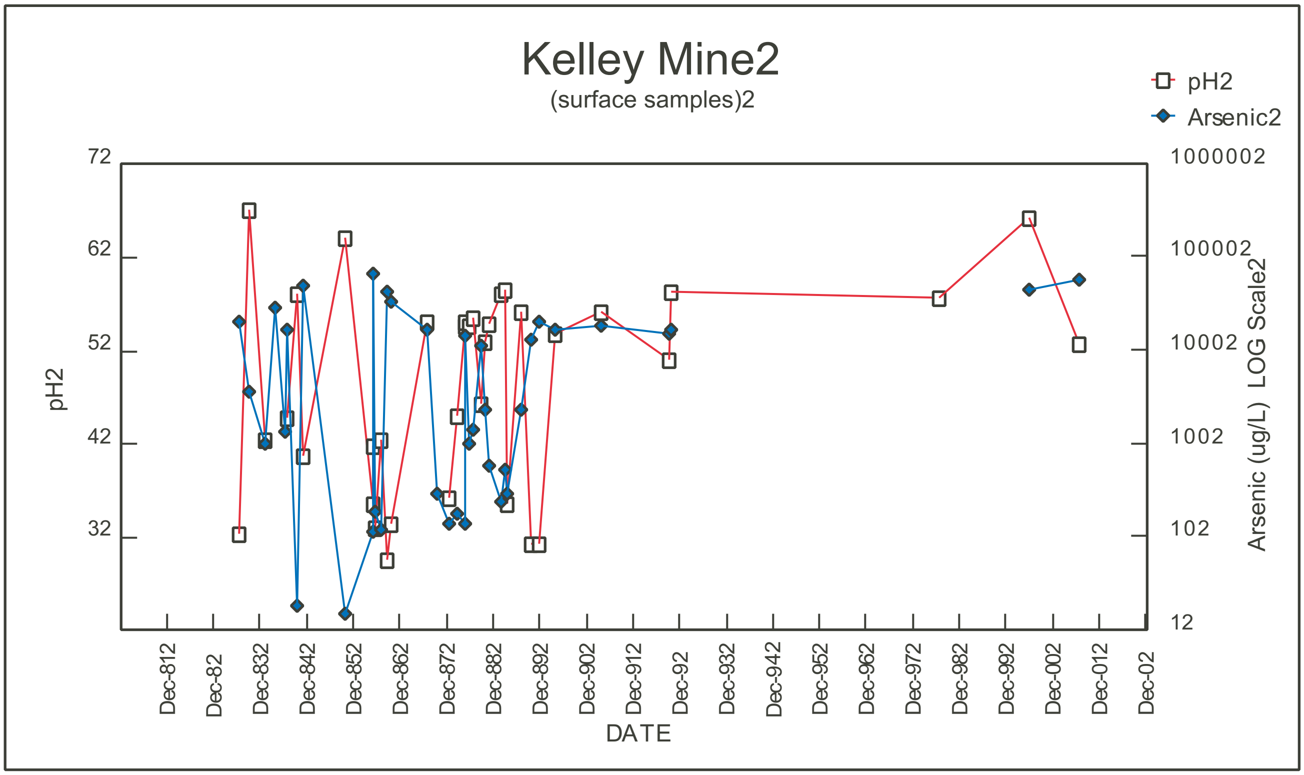
Table 2.2.0.1 Selected chemistry from East Camp Shafts, 2001- 2002 data

Mine	Sample Date	pH (S.U.)	Al (µg/L)	Fe (mg/L)	Pb (µg/L)	SO_4 (mg/L)	Zn (µg/L)
Kelley	07/18/01	5.08	2,730	460	5.17	2,780	159,000
	07/12/02	4.59	41,300	2,072	3.7	8,018	353,000
Anselmo	06/25/01	6.25	<20	0.02	<1	982	25,200
	07/11/02	6.38	46.9	32.8	<1	990	6,430
Granite Mountain	07/12/01	5.71	423	501	2.02	2,263	22,800
	not sampled in 2002						

Section 2.2.1 RI/FS Bedrock Monitoring Wells

Monitoring of the 9 RI/FS and ROD-installed bedrock wells continued. Monitoring well locations are shown on figure 2-26. Water levels continue to rise in wells A, C, D-1, D-2, G, and J at rates similar to those in the East Camp Mine system. Water levels in wells E and F continue to follow patterns identified in earlier reports. Table 2.2.1.1 contains yearly water-level changes and figure 2-35 shows these changes graphically.

The monitoring program contained in the 2002 CD specified that water levels be monitored on a continuous basis in bedrock wells A, B, C, and G. Water-level transducers were installed in each of these wells and set to collect water-level data every hour. This monitoring allows recording of



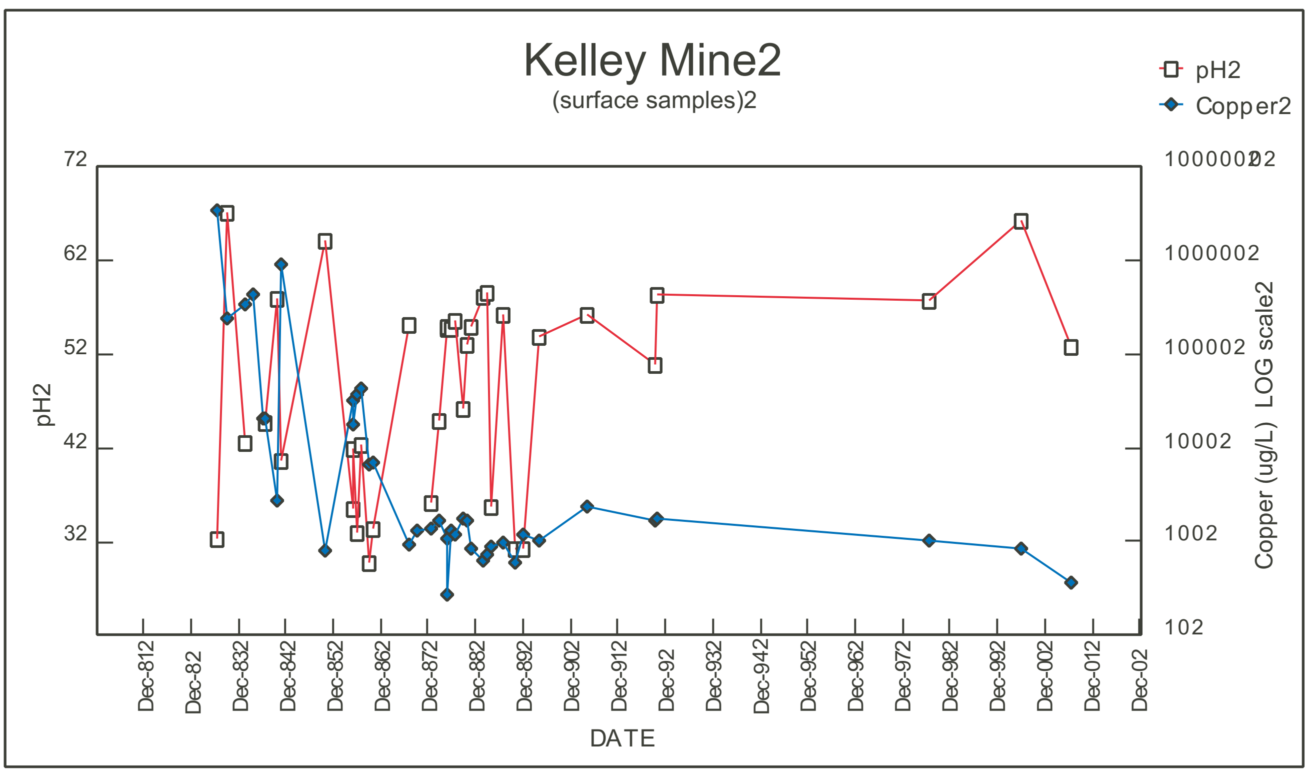
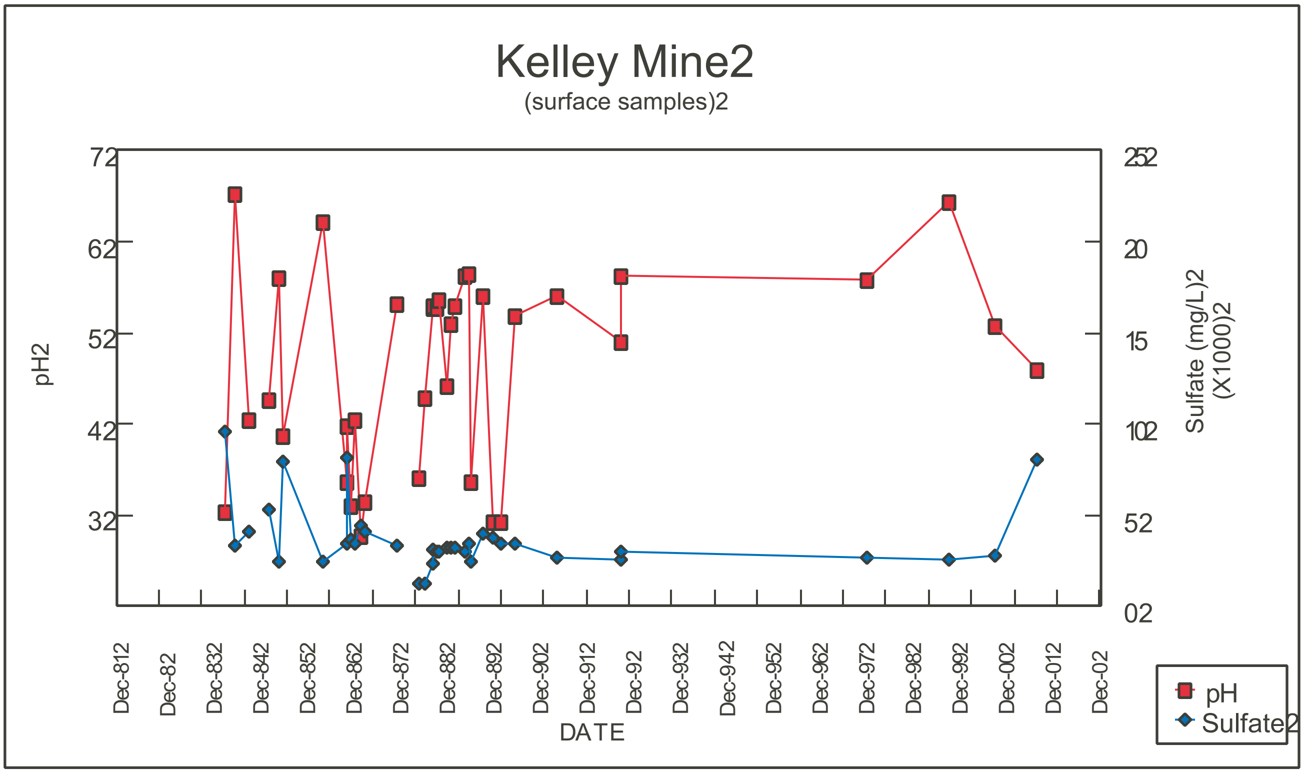


Figure 2-32. Arsenic and copper concentrations for the Kelley shaft (surface samples).2



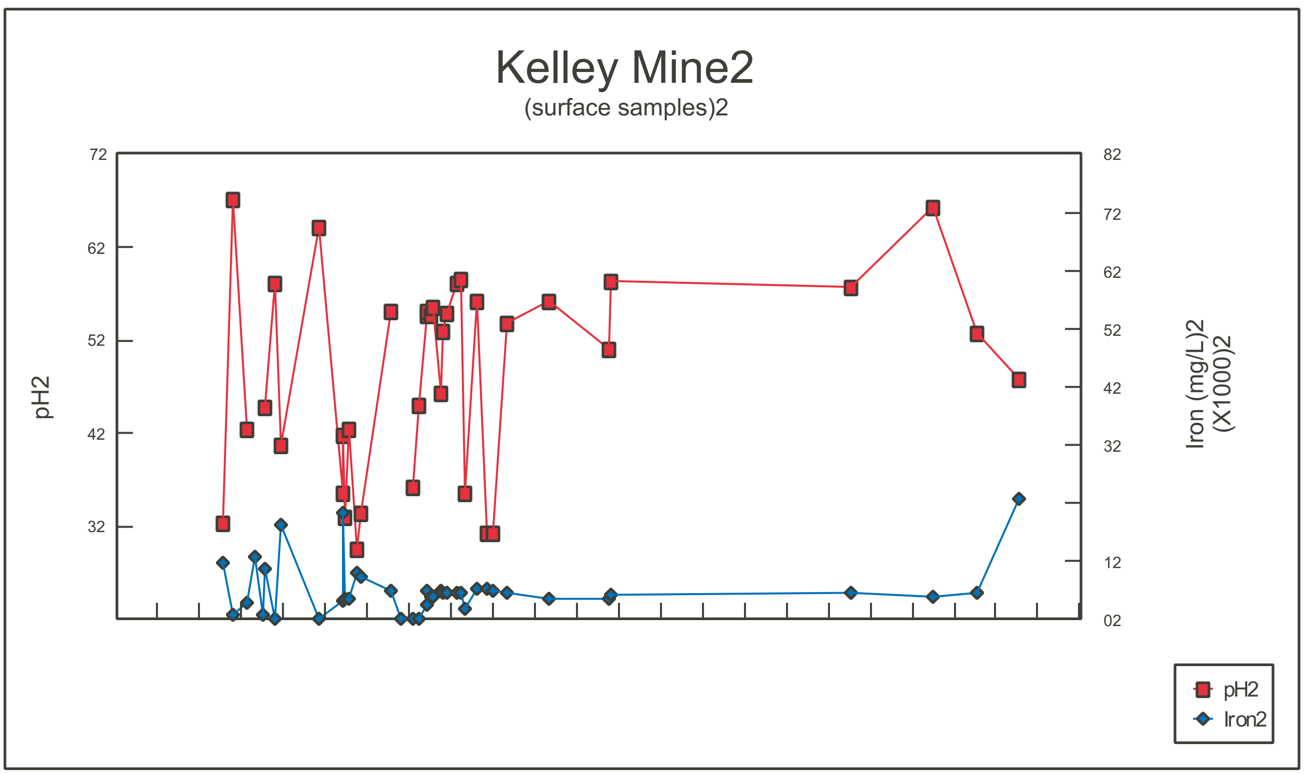
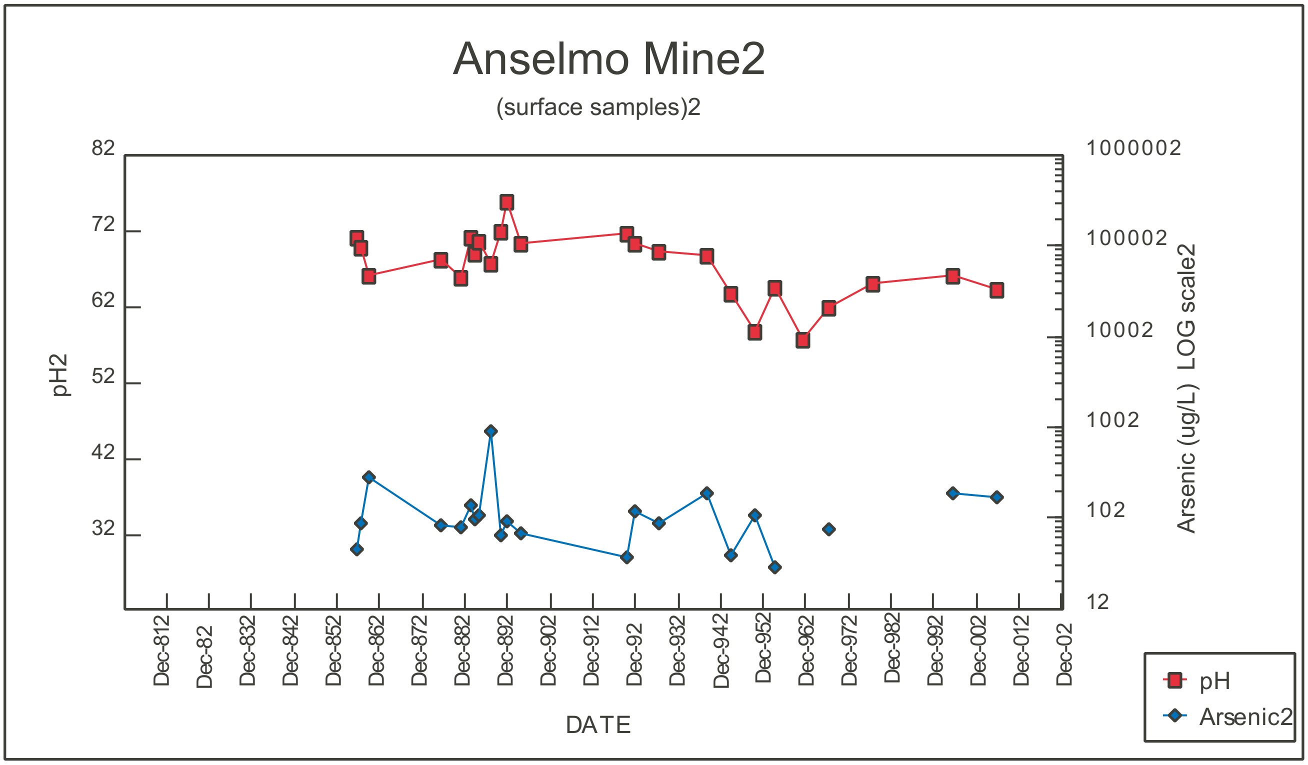


Figure 2-33. Sulfate and iron concentrations for the Kelley shaft (surface samples).2



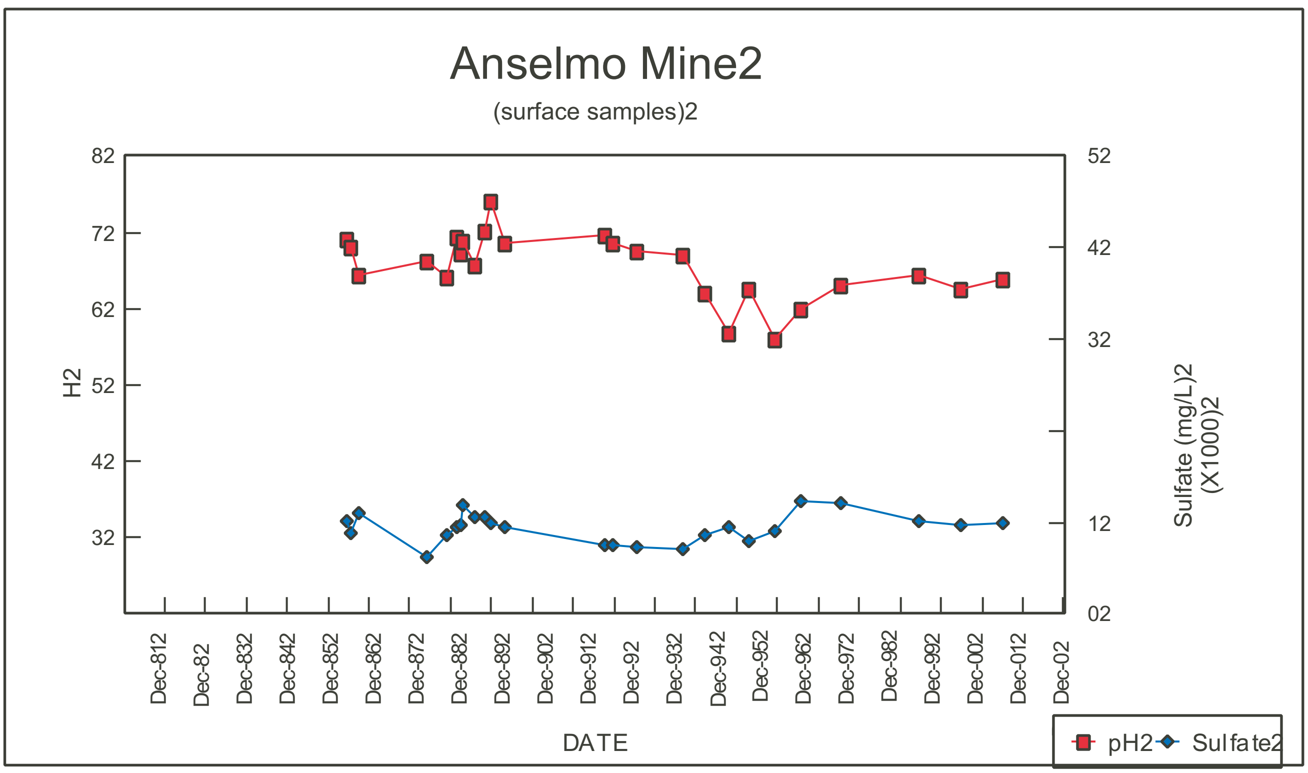


Figure 2-34. Arsenic and sulfate concentrations for the Anselmo shaft.2

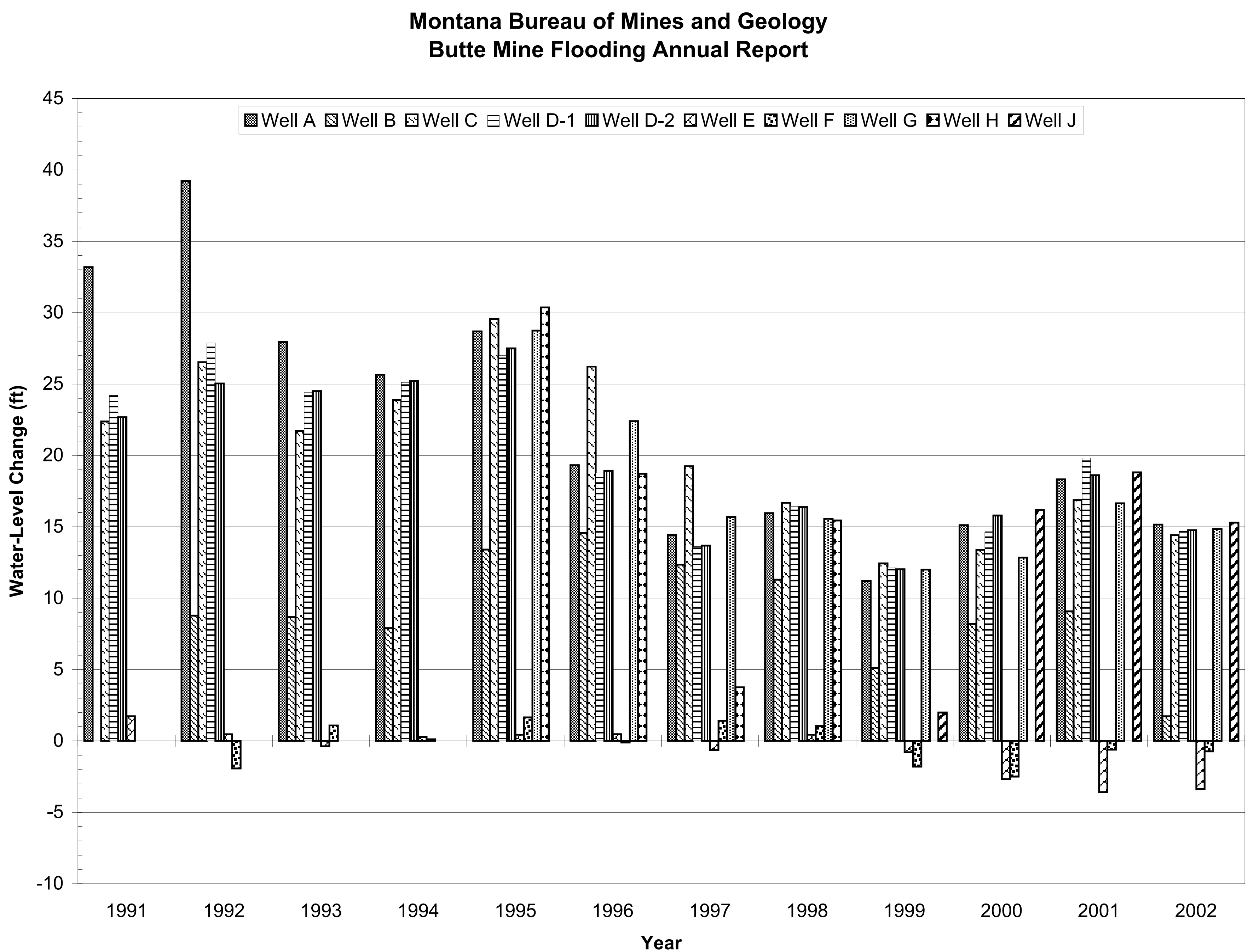


Figure 2-35. RI/FS bedrock wells annual water-level change.

Table 2.2.1.1 RI/FS Bedrock Well Annual Water-Level Change, in feet

Year	Well A	Well B	Well C	Well D-1	Well D-2	Well E	Well F	Well G	Well H	Well J
1989										
1990										
1991	33.18		22.38	24.20	22.68	1.73				
1992	39.22	8.78	26.53	27.89	25.04	0.47	-1.92			
1993	27.95	8.68	21.72	24.41	24.51	-0.37	1.09			
1994	25.65	7.90	23.88	25.12	25.21	0.27	0.11			
1995	28.69	13.41	29.55	26.99	27.50	0.44	1.65	28.74	30.37	
1996	19.31	14.56	26.22	18.77	18.92	0.48	-0.11	22.40	18.72	
1997	14.44	12.35	19.25	13.62	13.68	-0.64	1.41	15.67	3.76	
1998	15.96	11.30	16.68	16.41	16.39	0.44	1.03	15.56	15.44	
*Total 10-Year Change**	*204.4*	*76.98*	*186.21*	*177.41*	*173.93*	*2.82*	*3.26*	*82.37*	*68.29*	
1999	11.21	5.11	12.44	12.18	12.03	-0.78	-1.80	12.00	P&A	1.99
2000	15.12	8.20	13.39	14.66	15.79	-2.68	-2.49	12.84	P&A	16.19
2001	18.33	9.08	16.86	19.81	18.61	-3.58	-0.61	16.56	P&A	18.81
2002	15.16	1.73	14.41	14.69	14.76	-3.37	-0.73	14.84	P&A	15.29
*Total Change**	*264.22*	*101.10*	*243.31*	*238.75*	*235.12*	*-7.59*	*-2.37*	*138.70*	*68.29*	*52.28*

Year	DDH-1	DDH-2	DDH-4	DDH-5	DDH-8
1989	29.53			34.83	30.48
1990	36.24	30.99	5.44	27.61	35.96
1991	27.03	28.20	39.81	27.01	28.96
1992	28.25	26.09	37.66	31.07	26.16
1993	24.33	24.16	26.88	24.40	24.46
1994	25.00	25.65	28.34	19.78	15.97
1995	27.66	28.74	28.80	26.10	--
1996	18.53	18.97	20.24	12.41	55.68
1997	13.33	14.09	14.32	15.89	13.38
1998	15.03	16.20	16.25	16.50	16.50
**Total 10 Year Change*	*244.93*	*213.09*	*217.74*	*235.6*	*247.55*
1999	11.66	12.00	11.88	4.82	15.50
2000	14.64	16.11	14.77	P&A	10.42
2001	18.14	18.78	18.52	P&A	18.93
2002	14.63	14.80	13.14	P&A	13.64
*Total Change**	*304.00*	*274.78*	*276.05*	*240.42*	*306.04*

(*)Total change is the measured change. Access or obstructions prevented continuous water-level measurements at some sites. P&A - well plugged and abandoned due to integrity problems. Well J was drilled as a replacement for well H.

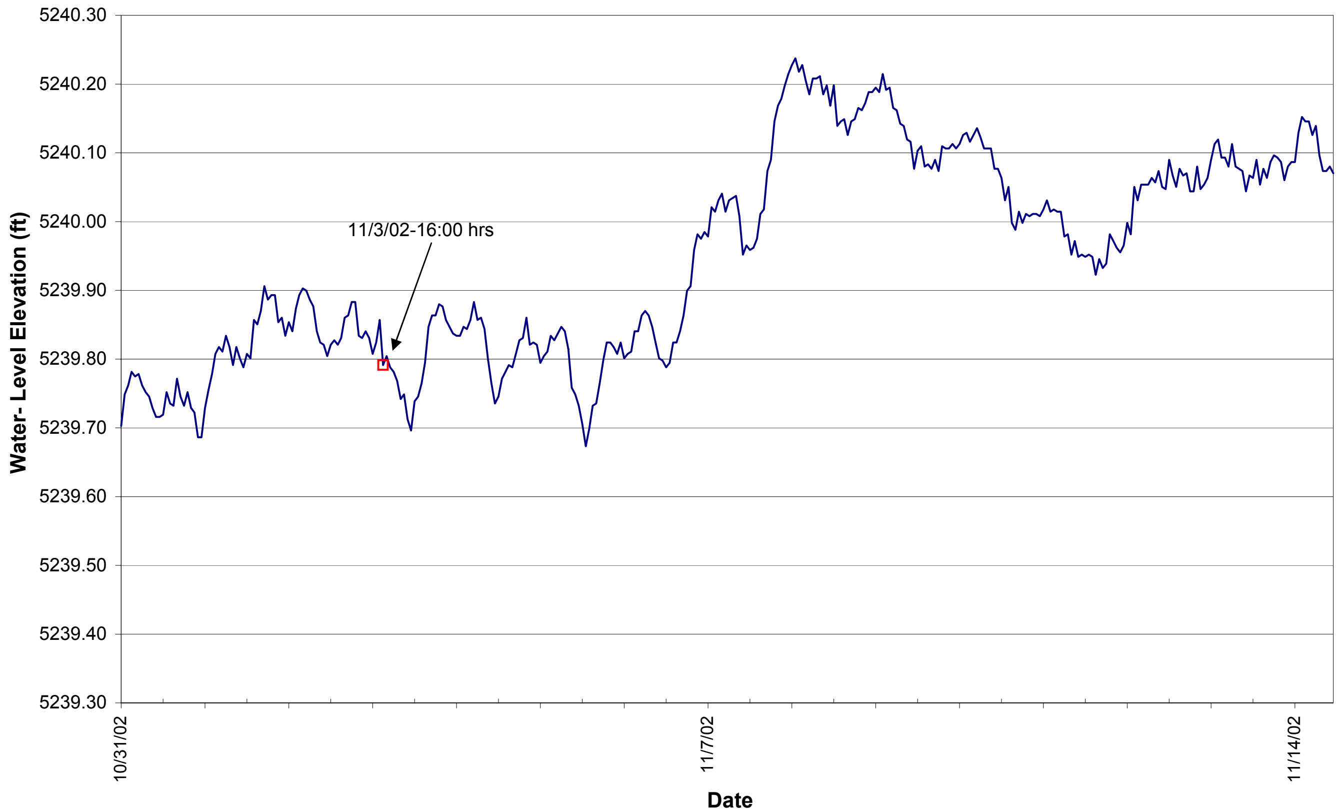
changes in water levels not seen when only one water-level measurement is taken monthly. On November 3, 2002, at 3:12 p.m., a magnitude 7.9 earthquake occurred in Alaska. A noticeable change in the 4:00 p.m. water level was seen in all four of these bedrock wells. Water levels declined briefly and then began to rise in their typical manner in wells C and G (figure 2-36). The water level declined for a longer period of time in well A before starting to rise again (figure 2-37).

The water level in well B responded differently than that of the other three wells. While the water level showed the same initial decline as the other wells, it continued to decline throughout the remainder of November and early December, before starting to level off. The water level in well B declined more than 5 feet during this period of time. Figure 2-38 shows this change in water level and the change in water level for well A for a comparison of trends. While no definitive explanation is available for the water-level change seen in well B, one possibility is that the ground movement associated with the earthquake actually increased leakage through adjacent fault zones. As water flowed into the fault(s) a decline in water levels occurred. Water levels would decline until the fractures in the bedrock were filled with water, or were gradually sealed again, and then would begin to rise. Considering that the location of this well is near the Continental Fault and its location is in an area not as impacted by historic mining and mine dewatering, and the fact that this well's water level was a hundred feet higher than other bedrock well water levels, this possibility seems plausible.

Except for the temporary changes following the November Alaskan earthquake, water-level trends in wells A, C, D-1, D-2, G, and J followed those identified in previous reports. Figures 2-39 and 2-40 are hydrographs for selected wells A, D-1 and D-2. The continued and steady rise in water levels is very apparent. Precipitation is also shown on these figures to compare water-level changes to precipitation. Unlike a number of the shallow alluvial wells, no variations in water levels are noted either seasonally or yearly as a result of precipitation. Water-levels in the bedrock aquifer, which had been affected by historic underground mine dewatering, are responding to the cessation of pumping and show no apparent relationship to precipitation through 2002. Instead, physical changes that affect the flow of water into the Berkeley Pit and underground mines, e.g. the 1996 HSB water diversion and the 2000 addition of the HSB drainage flow, are very apparent, and are the major influences on water-level increases (figure 2-41). The void areas in the mines and Berkeley Pit control the annual rate of rise in this system.

Water levels measured in well J since its completion in 1999 have been in the same range as those in other surrounding bedrock wells, and are shown on figure 2-42. Historic water levels for well H are shown on this figure with a linear projection of water levels included. Water levels for well J plot very close to those projected for well H, verifying that well J was completed in the same bedrock zone as well H.

The water-level change in well B continued to increase at about one-half the rate of that of the above bedrock wells and Berkeley Pit over the past several years, until November 2002. Since 1992, the rate of water-level rise in this well had been about 46 percent that of the Berkeley Pit. Due to the water-level decline during November and December, the 2002 rate of water-level rise was only 11 percent of that of the Berkeley Pit. Hydrographs for wells A and B, showing monthly water-level elevations are shown on figure 2-43.



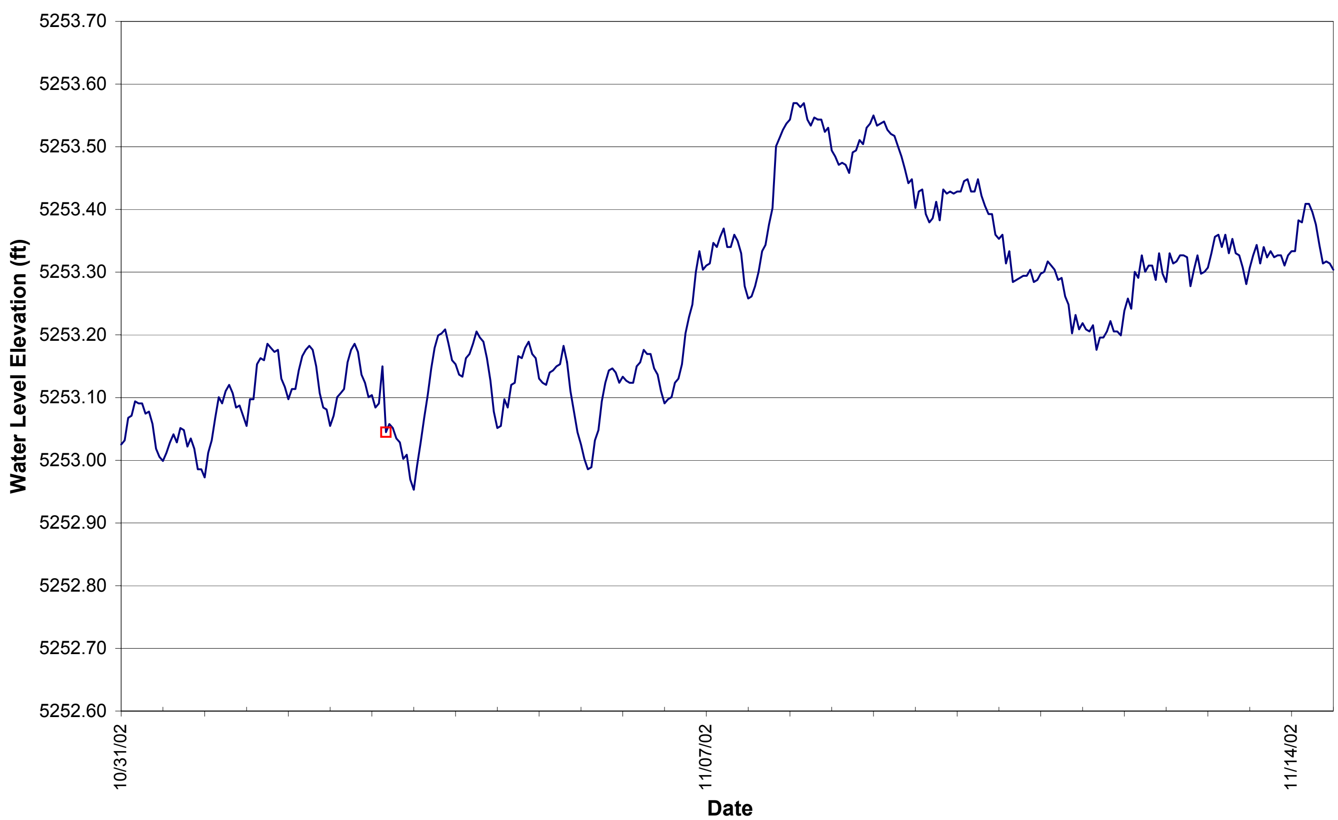


Figure 2-36. Water-level hydrographs showing the influence of the November 3, 2002 Alaska earthquake on bedrock wells C (top) and G (bottom).

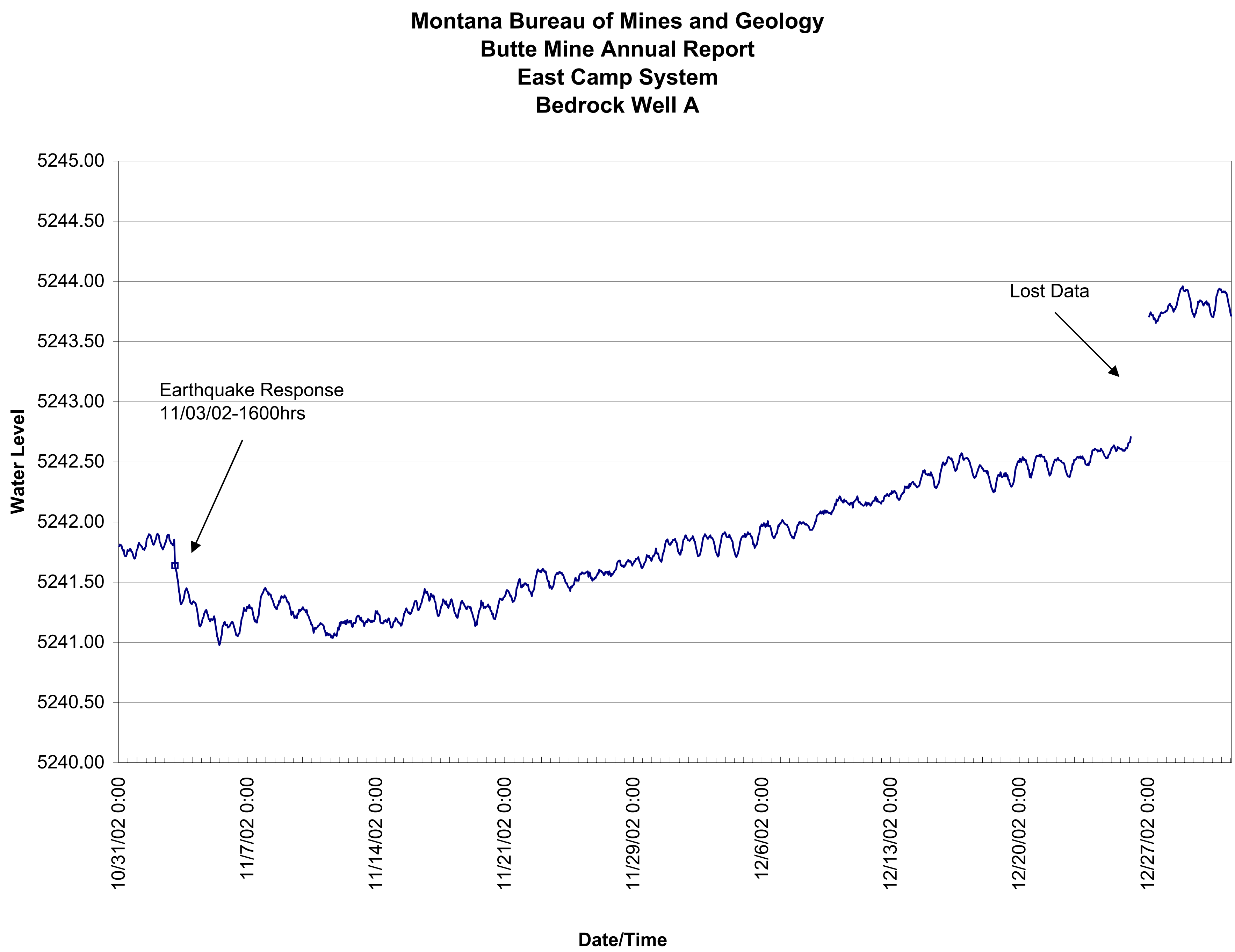


Figure 2-37. Water-level hydrograph showing the influence of the November 3, 2002 earthquake on bedrock well A.

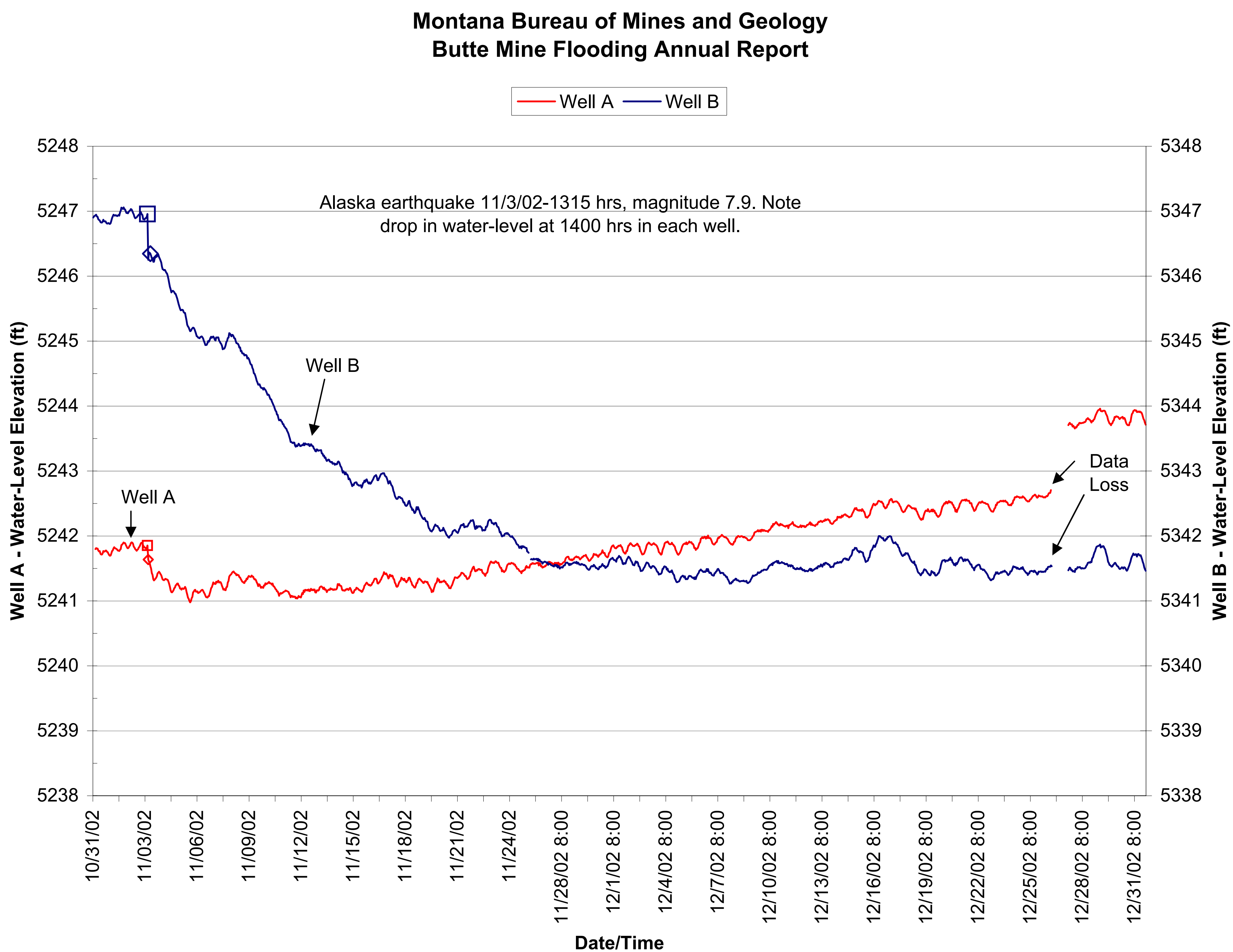


Figure 2- 38. Water-level hydrographs for bedrock wells A and B showing the influence on water levels from the November 2002 Alaska earthquake.

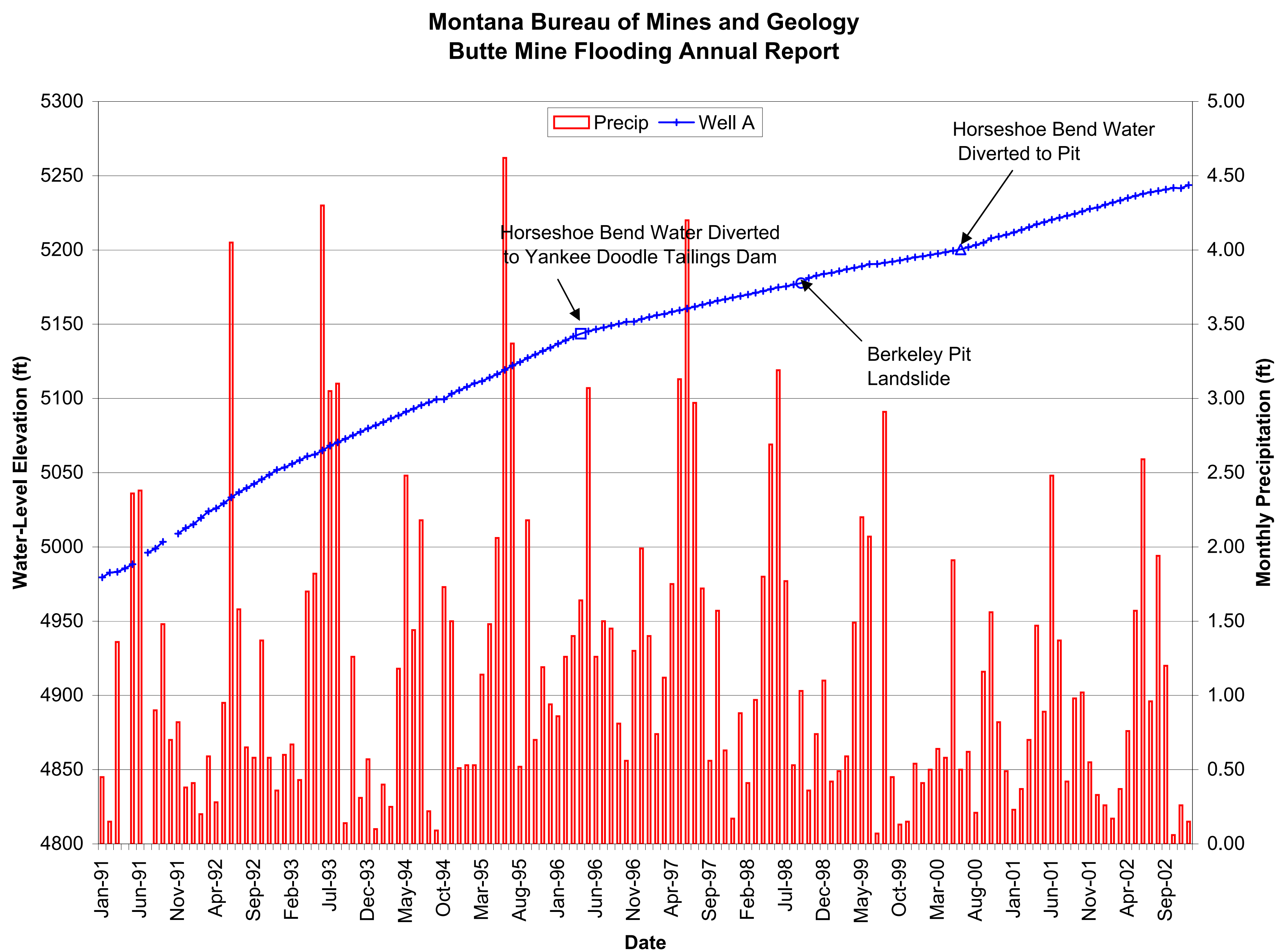


Figure 2-39. Water-level hydrograph for bedrock well A.

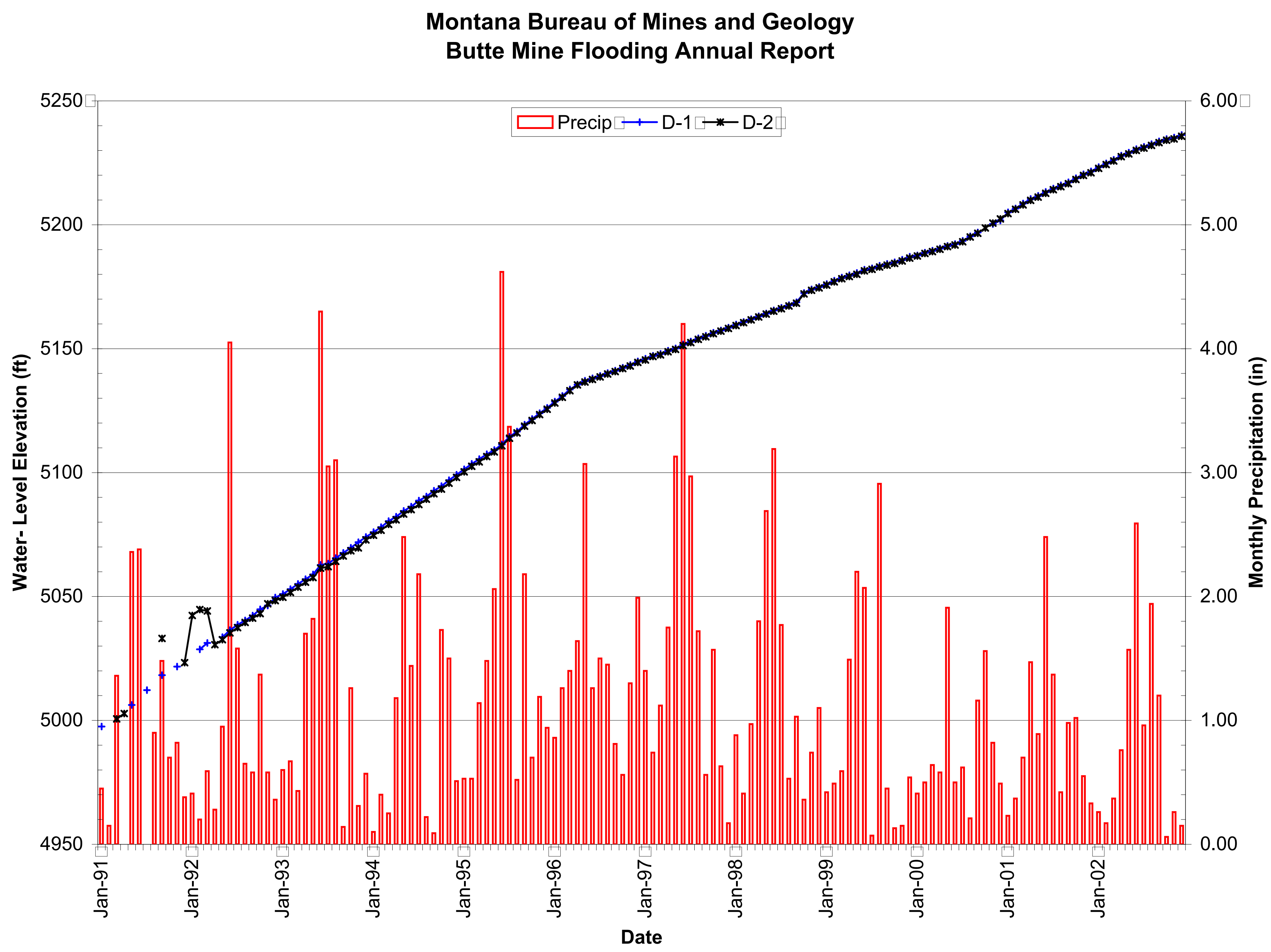


Figure 2-40. Water-level hydrographs bedrock wells D-1 and D-2.

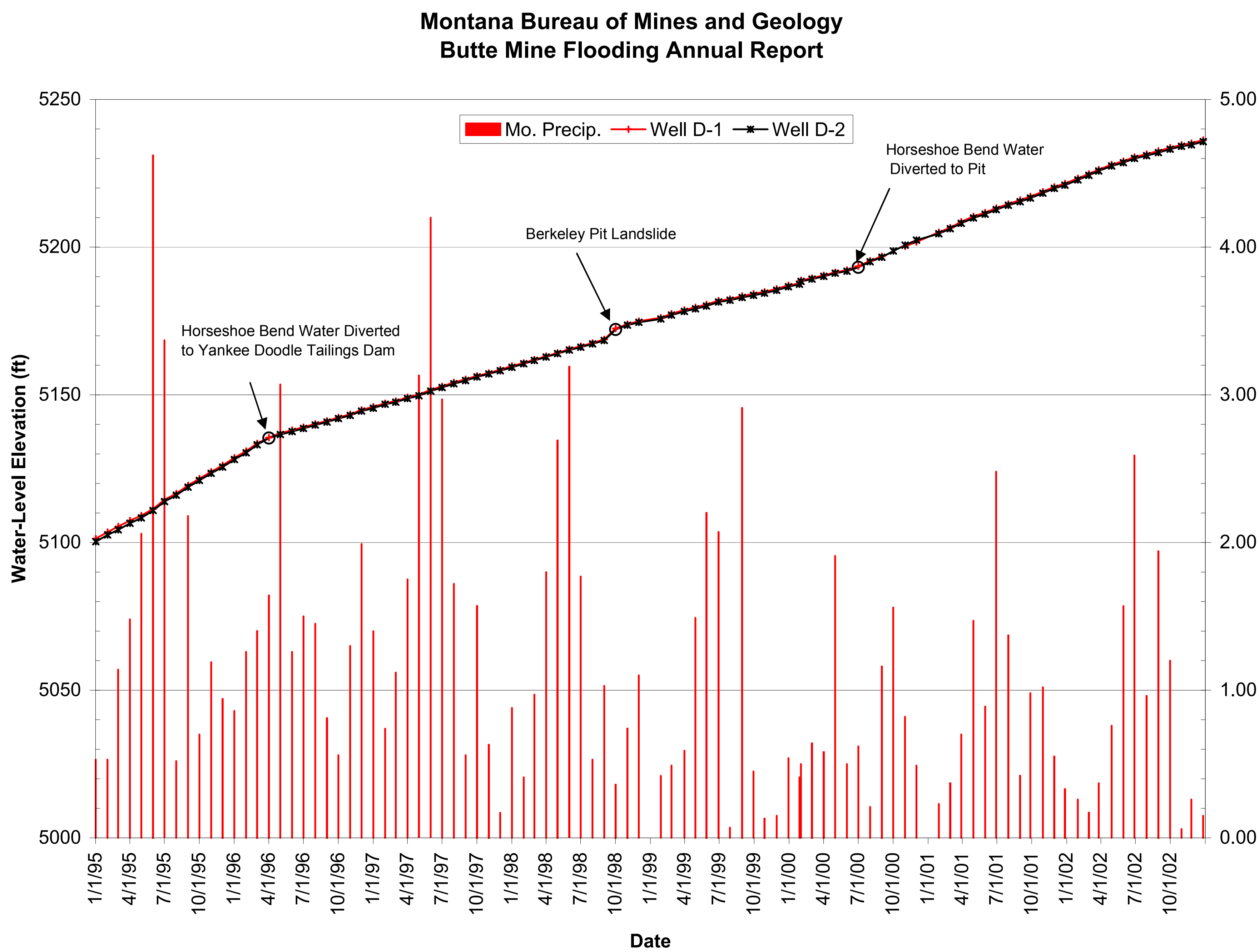


Figure 2-41. Water-level hydrographs, 1995-2002, wells D-1 and D-2.

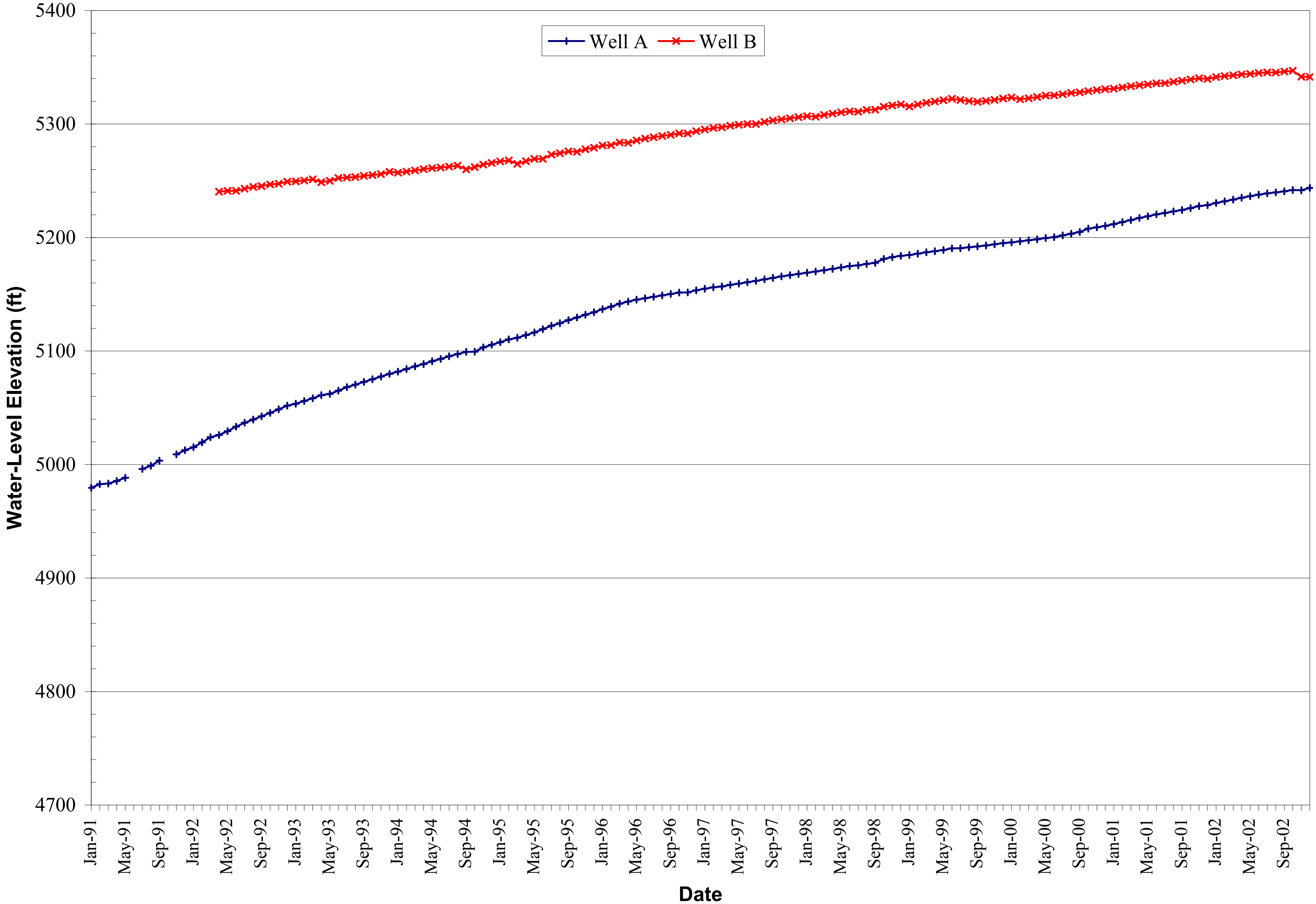


Figure 2-43. Water-level hydrograph for bedrock wells A and B.

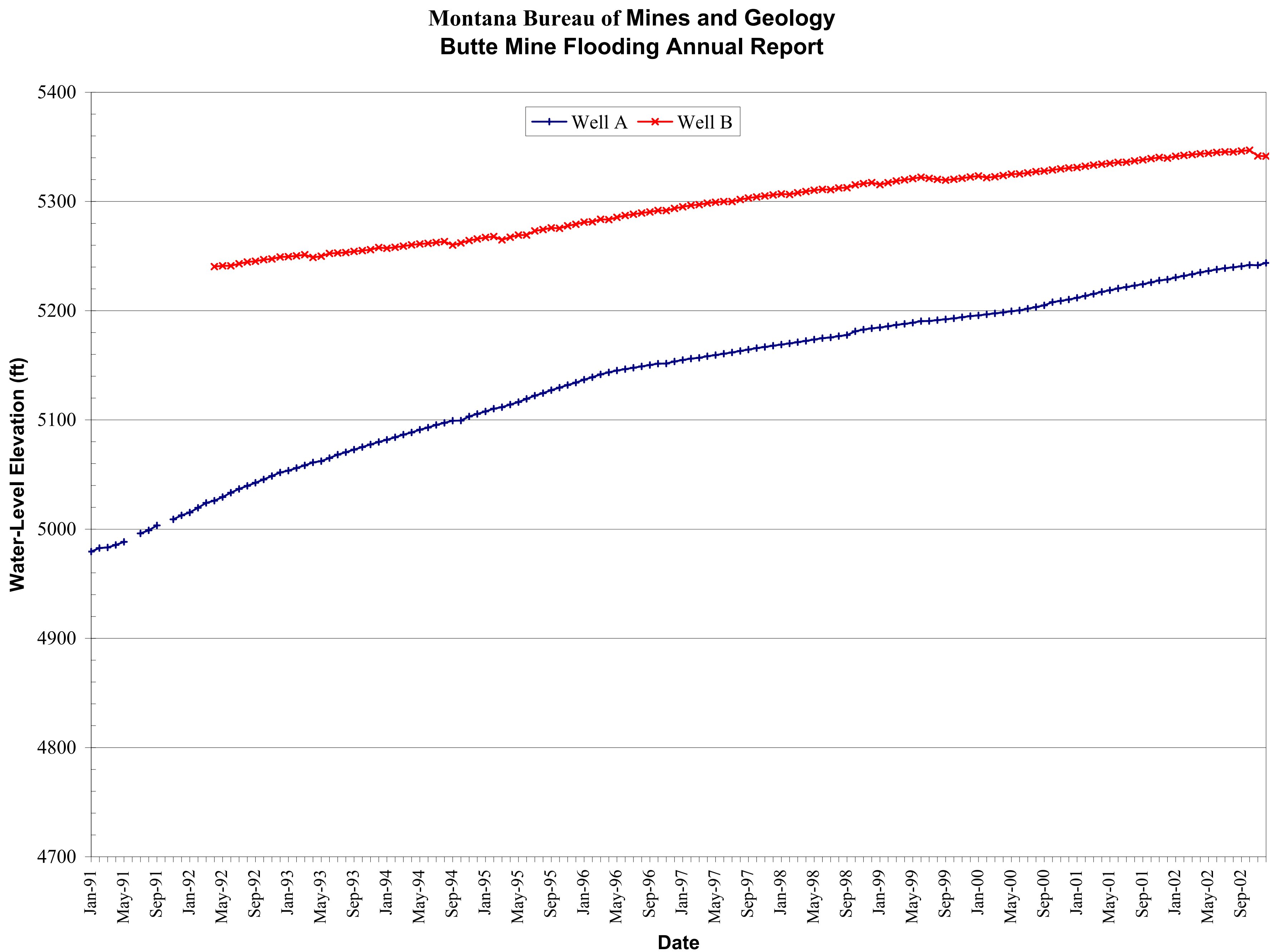


Figure 2-43. Water-level hydrograph for bedrock wells A and B.

Water levels in wells E and F do not follow the trends seen in the other bedrock wells (figure 2-44). They are considerably higher than those in the other bedrock wells, indicating a lack of dewatering from historic mining activities.

Water-level monitoring continues to confirm that the flow of water in the affected bedrock aquifer is towards the Berkeley Pit. The potentiometric-surface map (figure 2-45) for the East Camp bedrock aquifer shows the flow of water from all directions is towards the pit.

Section 2.2.1.1 RI/FS Bedrock Well Water Quality

Most of the wells used for water-quality monitoring in the East Camp bedrock aquifer have shown only slight changes in 2002. There are several wells, however, for which concentrations of individual constituents have changed considerably. For example, well D-2 presents an unusual case where arsenic has decreased from about 45 μg/L in 2001 to less than detection limits (5.3 μg/L) in 2002. Similarly, zinc concentrations in well D-2 decreased from 6,040 μg/L in 2001 to less than the detection limit of 10.5 μg/L. The concentration of aluminum in well C decreased from 482 μg/L to less than 24 μg/L. Similar dramatic decreases in concentration were reported for wells F and G. As with several of the East Camp shafts, the authors are reluctant to call these trends based on a single datum.

Table 2.2.1.1.1 summarizes the water-quality trends over the past few years; the status of wells B and D-1 (figure 2-46) changed with respect to exceeding MCLs due to the change in the water-quality standard of arsenic from 18 to 10 μg/L. Arsenic concentrations in well B have increased from about 10 μg/L in 2,000 to about 16 μg/L in 2002. Arsenic concentrations in well D-1 have decreased from about 25 μg/L in 2000 to 10.13 in 2002.

Section 2.2.2 DDH Series Wells

Water-level monitoring of the DDH series wells continued. Water levels have continued to rise in these wells, following previous trends. The water-level rise in wells DDH-1, DDH-2, DDH-4, and DDH-8 ranged from 13.14 to 14.80 feet in 2002. The rates of rise are consistent with those of the other bedrock wells and East Camp mine shafts. Figure 2-47 shows hydrographs for wells DDH-2 and DDH-4 showing water-level increases. Once again precipitation does not show any affect on water-level rise.

No water-quality samples were collected from these wells, as they are used for water-level monitoring only.

Section 2.2.3 Berkeley Pit, Continental Pit, and Horseshoe Bend Drainage

The Berkeley Pit water-level elevation was surveyed each month to coincide with monthly water-level monitoring in wells. Figure 2-48 is a hydrograph showing the pit's water-level rise over time. The

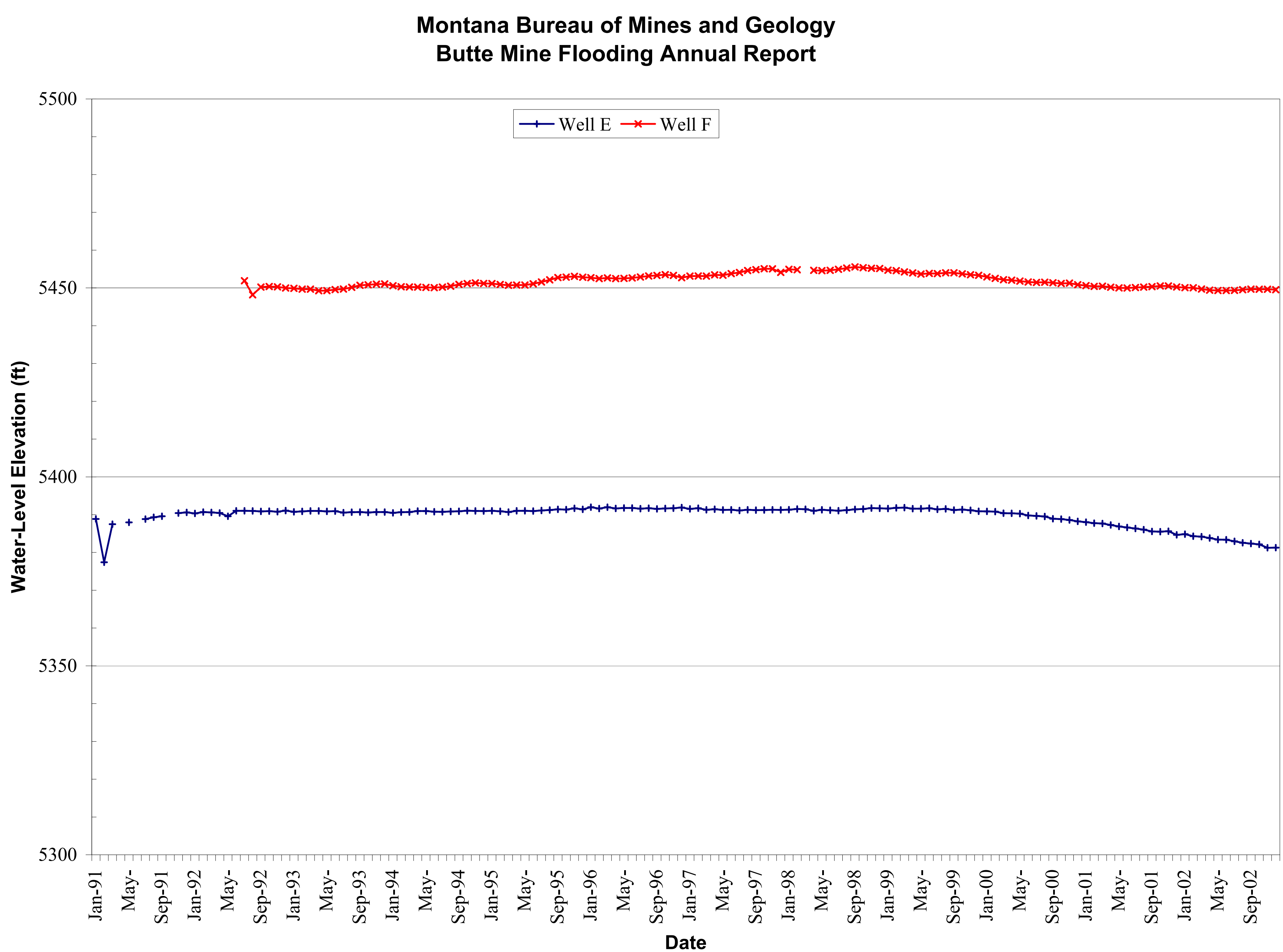


Figure 2-44. Water-level hydrograph for bedrock wells E and F.

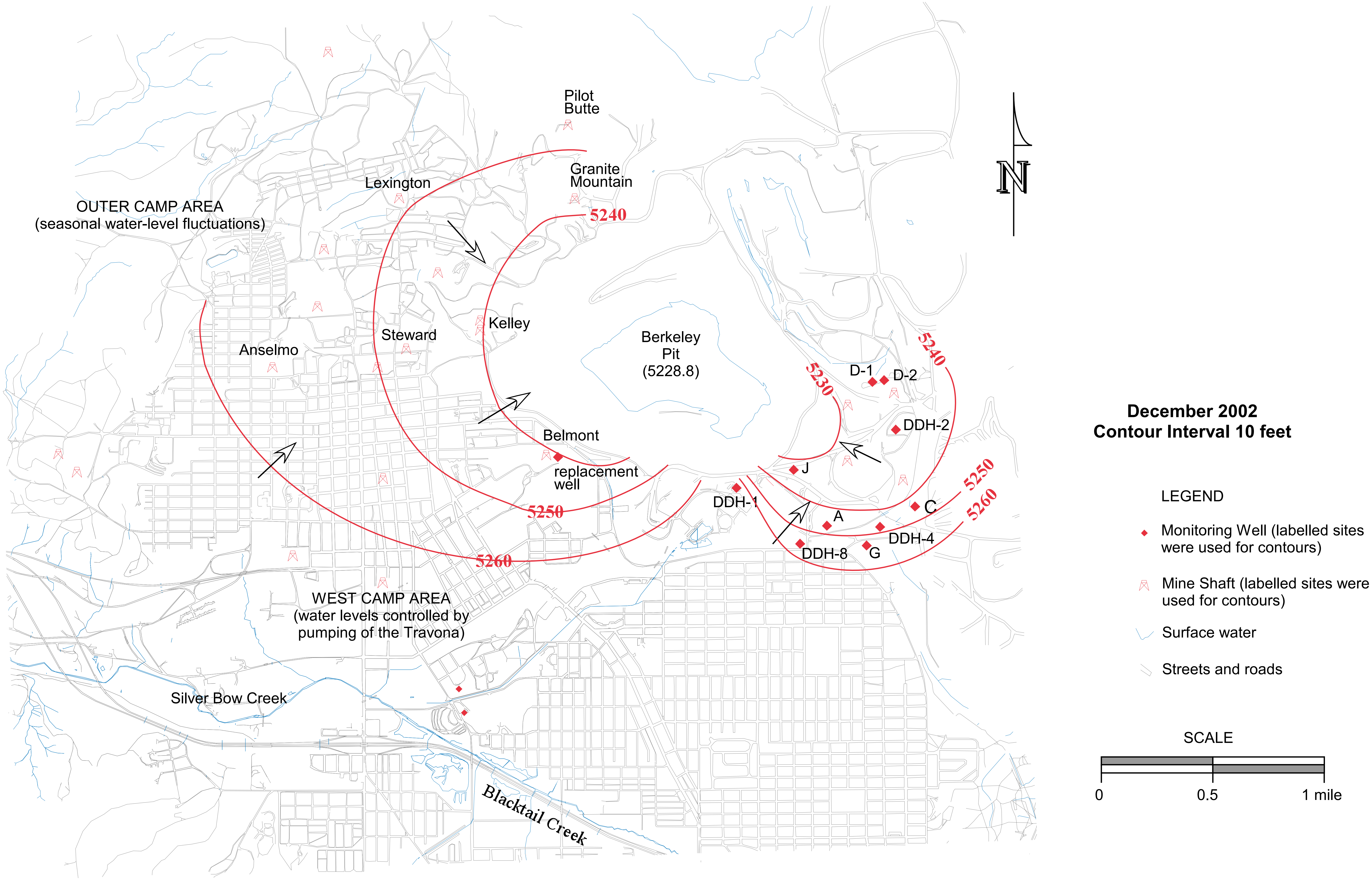
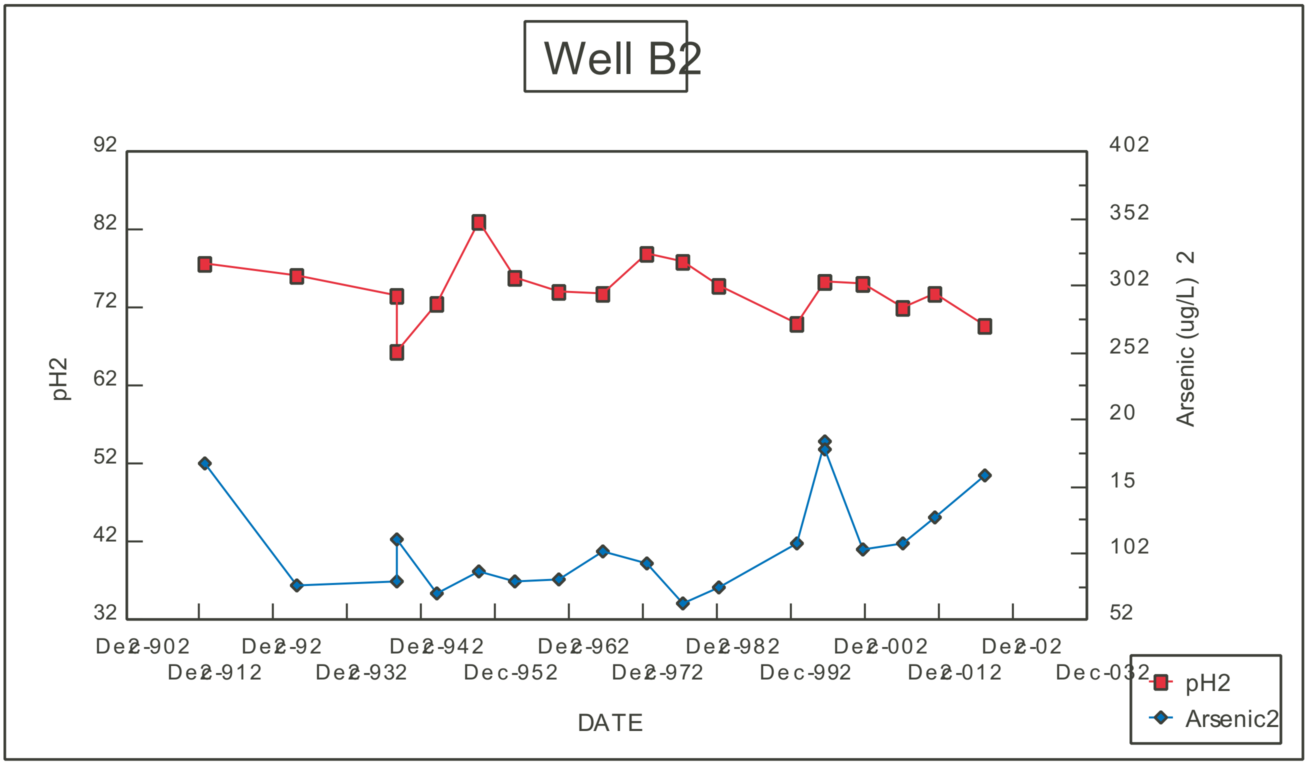


Figure 2-45. East Camp Bedrock Aquifer Potentiometric Map, December 2002 Water Levels; arrows indicate direction of ground-water flow (contour interval is 10 feet)



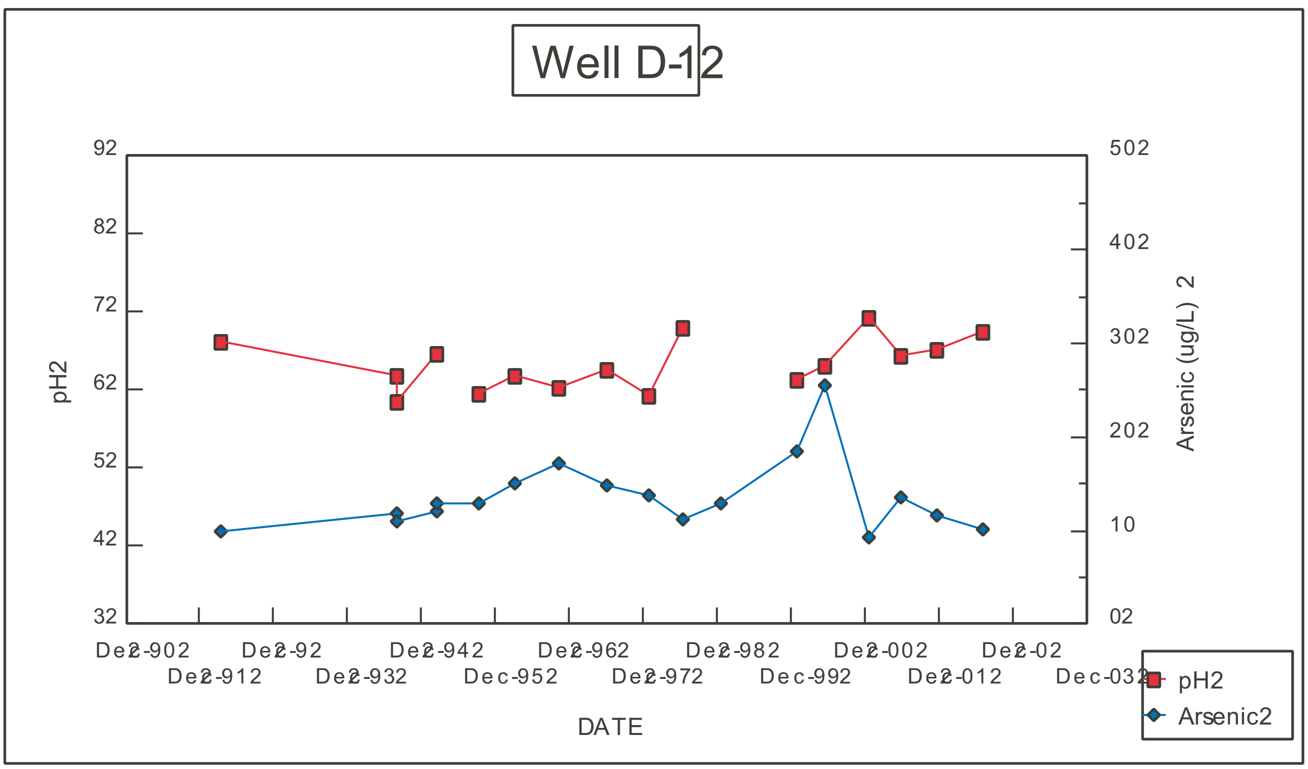


Figure 2-46 Arsenic concentrations for bedrock wells B and D-1.2

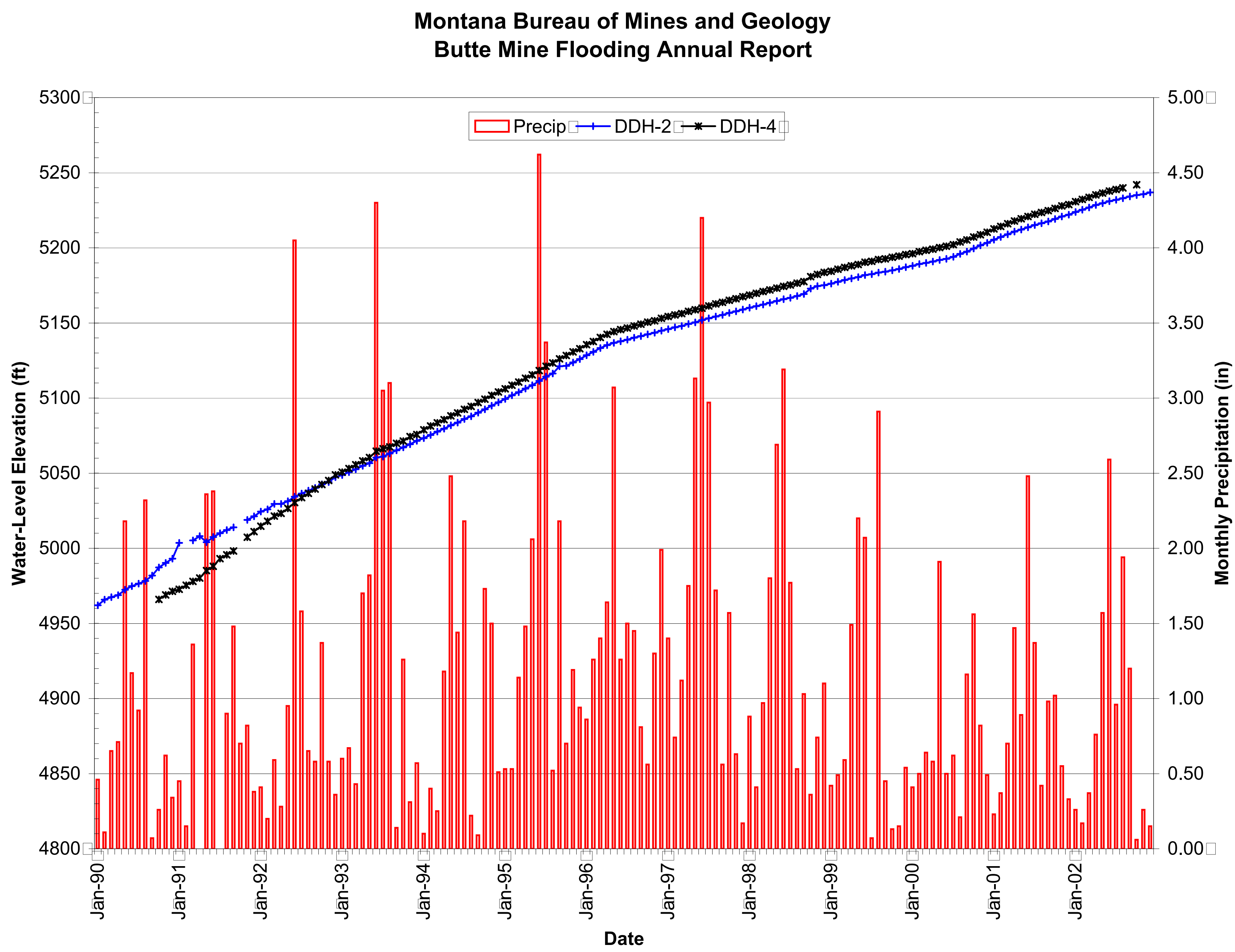


Figure 2-47. Water-level hydrographs for bedrock wells DDH-2 and DDH-4.

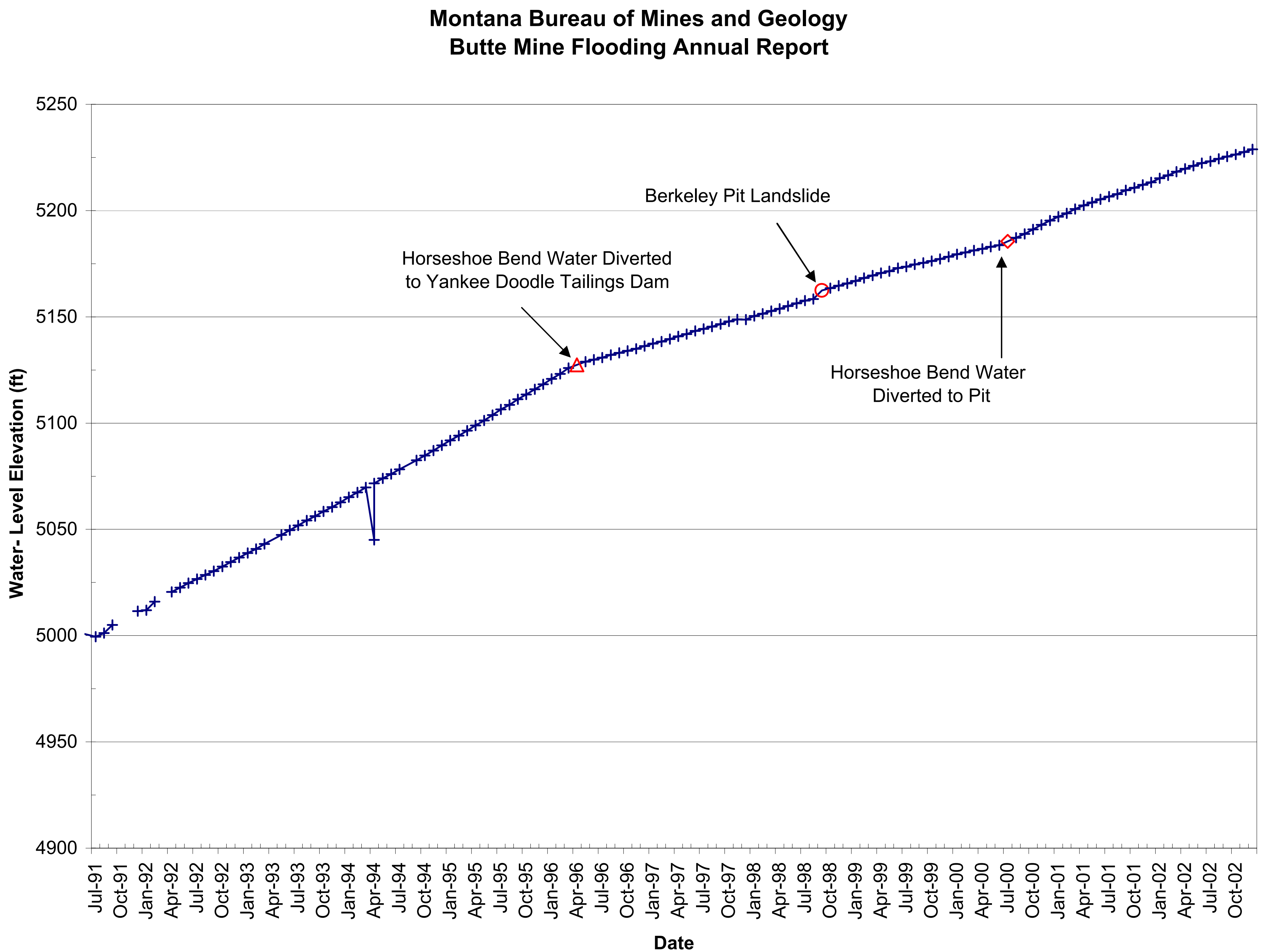


Figure 2-48. Water-level hydrograph for the Berkeley Pit.

Table 2.2.1.1.1 Exceedences and trends for East Camp bedrock wells, 1989 through 2002; arsenic MCL changed from 18 to 10 µg/L.

Well Name	Exceedences* (±1)	Concentration Trend	Remarks
A	Y	variable	arsenic (MCL), sulfate (SMCL)
B	Y	variable	arsenic (MCL), sulfate (SMCL)
C	N	variable	sulfate (SMCL)
D-1	Y	variable	arsenic (MCL), sulfate (SMCL)
D-2	N	variable	sulfate (SMCL)
E	Y	variable	sulfate (SMCL), arsenic (MCL)
F	Y	none	arsenic (MCL), sulfate (SMCL)
G	N	decrease	sulfate (SMCL)
J	Y	variable	very poor quality water

(*) excludes sulfate

overall trend is similar to that of previous years. There are three noticeable changes on this figure. The first change represents a decrease in the filling rate (seen as a change in slope on the graph) when the HSB drainage diversion occurred in April of 1996; the second is an almost instantaneous water-level rise from the September 1998 landslide; and the third depicts an increased filling rate (seen as a change in slope on the graph) following MR's June 2000 suspension of mining and the subsequent inflow of water from the HSB drainage to the pit. From April 1996 through June 2000, water from the HSB drainage was diverted and incorporated into the mining and milling process. Following the June 2000 suspension of mining, water from the HSB drainage was again allowed to flow into the Berkeley Pit. The volume of water allowed to enter the pit exceeded 2.6 billion gallons from July 2000 through December 2002 (figure 2-49). This represents an average flow of 2,020 gallons per minute (gpm) and a net input of 800 million gallons of additional water during 2002. The overall Berkeley Pit water-level rise for 2002 was 15.56 feet.

As discussed previously, the 90° V-notch weir was relocated upstream in the HSB drainage to accommodate infrastructure changes associated with the water-treatment plant construction. Construction activities affected flow monitoring at times from April through October 2002. Flow rates during this period were based upon occasional transducer readings and field measurements. While construction activities affected the collection of continuous flow data, it does appear that the flow of water in this drainage is becoming less. Flows measured at the HSB Falls flume averaged 255 gpm for the year. This flow is well below the historic flows of 1,000 gpm or more reported by MR. The decreased flow from this source would account for a large portion of the flow change seen in the HSB drainage for 2002.

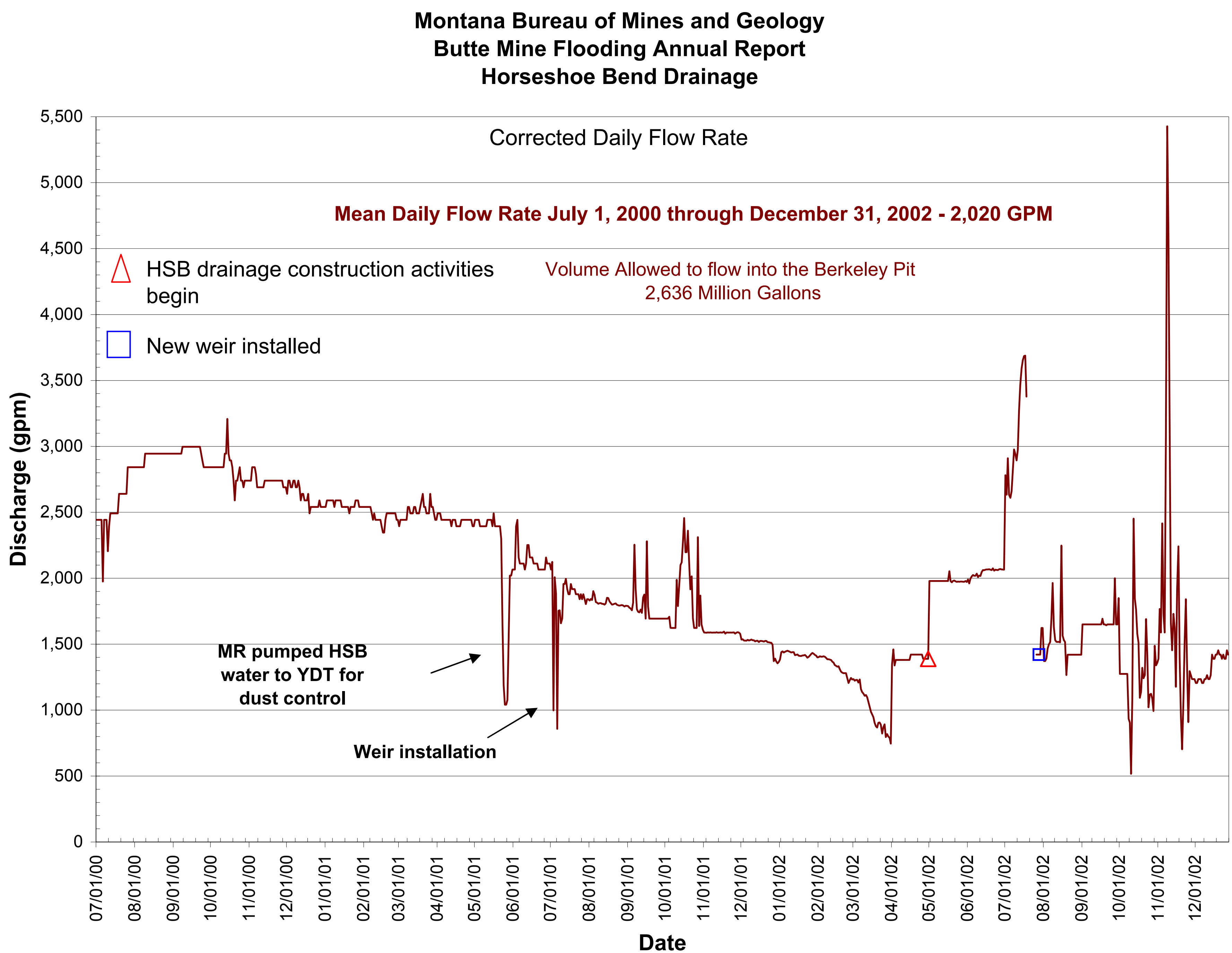


Figure 2-49. Horseshoe Bend Drainage daily average flow rate, July 1, 2000 through December 31, 2002.

The Continental Pit water level was measured by monitoring the water level in the Sarsfield dewatering well. The pump in the dewatering well operated sporadically during the summer and fall. Water from this well was used for road dust control. A total of 9.2 million gallons of water was pumped during that time. The water level in this well rose over 14 feet during 2002, resulting in about 28 feet of standing water in the pit bottom.

Section 2.2.3.1 Berkeley Pit, Continental Pit, and Horseshoe Bend Drainage Water Quality

The concentration of most dissolved constituents in the upper 100 feet of the Berkeley Pit water continues to reflect the influence of the inflowing waters. Concentrations of most dissolved constituents generally decreased after the diversion of surface water from the pit in 1996 and then increased after surface water was re-introduced in 2000. Data collected in 2002 indicate another reversal, with pH decreasing and the concentration of most dissolved constituents increasing (figure 2-50a). Samples collected from 100 to 400 feet below the surface 2002 show only a slight change from the previous results (figure 2-50b). Data collected in 2002 indicate that Fe^{3+}/Fe^{2+} ratios for the Berkeley Pit have shown a departure from past data. The ratio for the deeper water is consistently in the range of 0.1 to 0.5; the ratio of surface samples ranges from about 1.5 to about 3. Data collected in 2002 indicate similar values for the samples collected 100 to 400 feet below the surface, but a much higher ratio (21 to 260) in the surface samples.

There has been a general decrease in concentration of several constituents in the HSB flow since 1994, but the shut down of the leach pads in 1999 effected a greater rate of decrease (figure 2-51). As noted, flow from this area fluctuated during the year, but the net change was a decrease in flow. Water-quality data were collected 12 times, roughly at one-month intervals in 2002; the concentrations of most constituents declined slightly and were consistent with the overall trend of the last few years.

Water quality of the HSB outflow continues to be slightly better than that of the Berkeley Pit (table 2.2.3.1). This has been the case throughout the period of record and reflects the sustained geochemical processes within the pit.

Water-quality data for the Continental Pit area were collected from the Sarsfield dewatering well and from water accumulating in the bottom of the Continental Pit. The well was pumped intermittently and, when operating, discharged about 250 gpm; 7 samples were collected in 2002. Water quality varied, but no trend was apparent in any of the dissolved constituents. Selected data for the dewatering well and the pit are presented in table 2.2.3.1

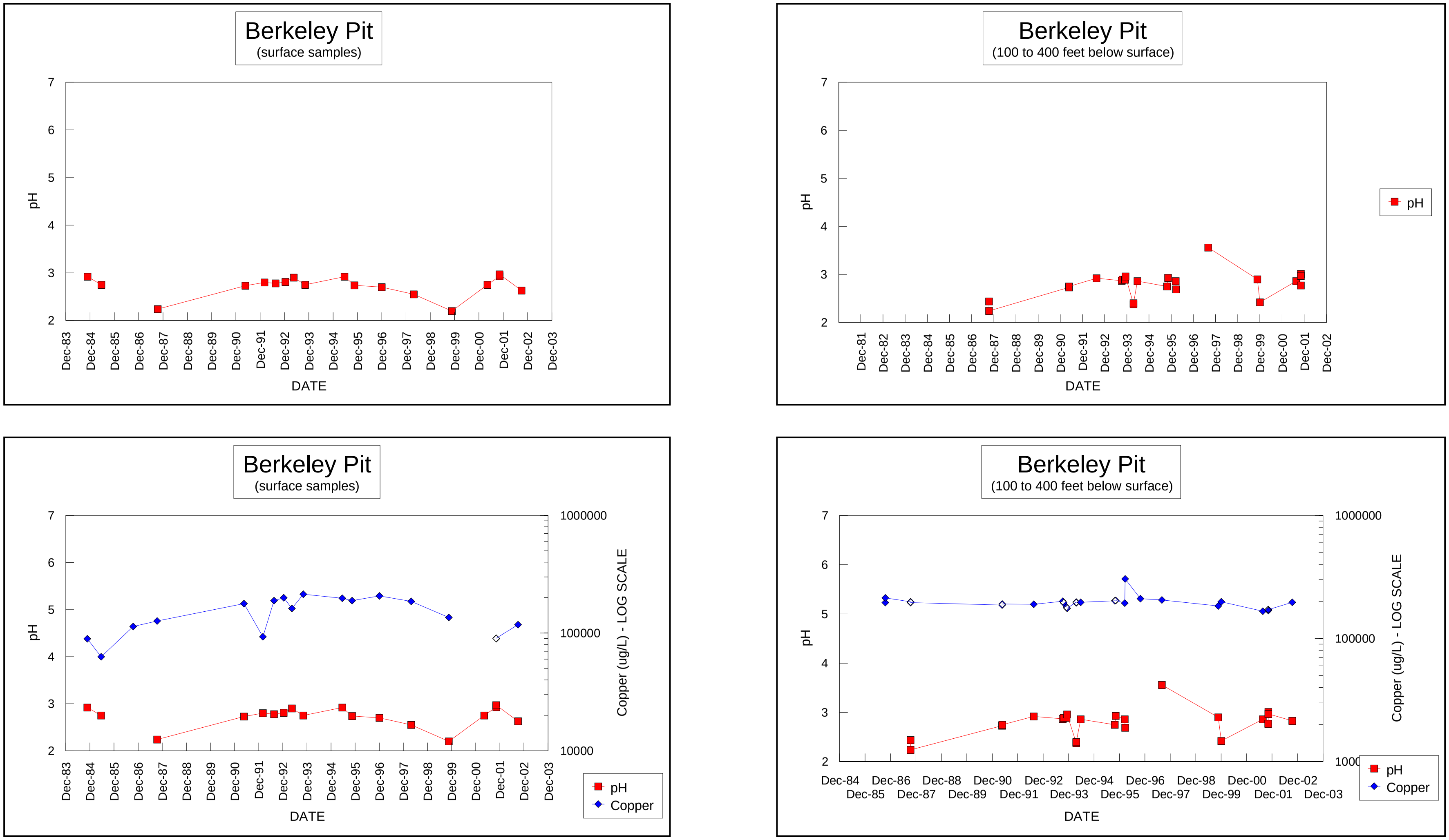


Figure 2-50a. Selected chemistry for the Berkeley Pit

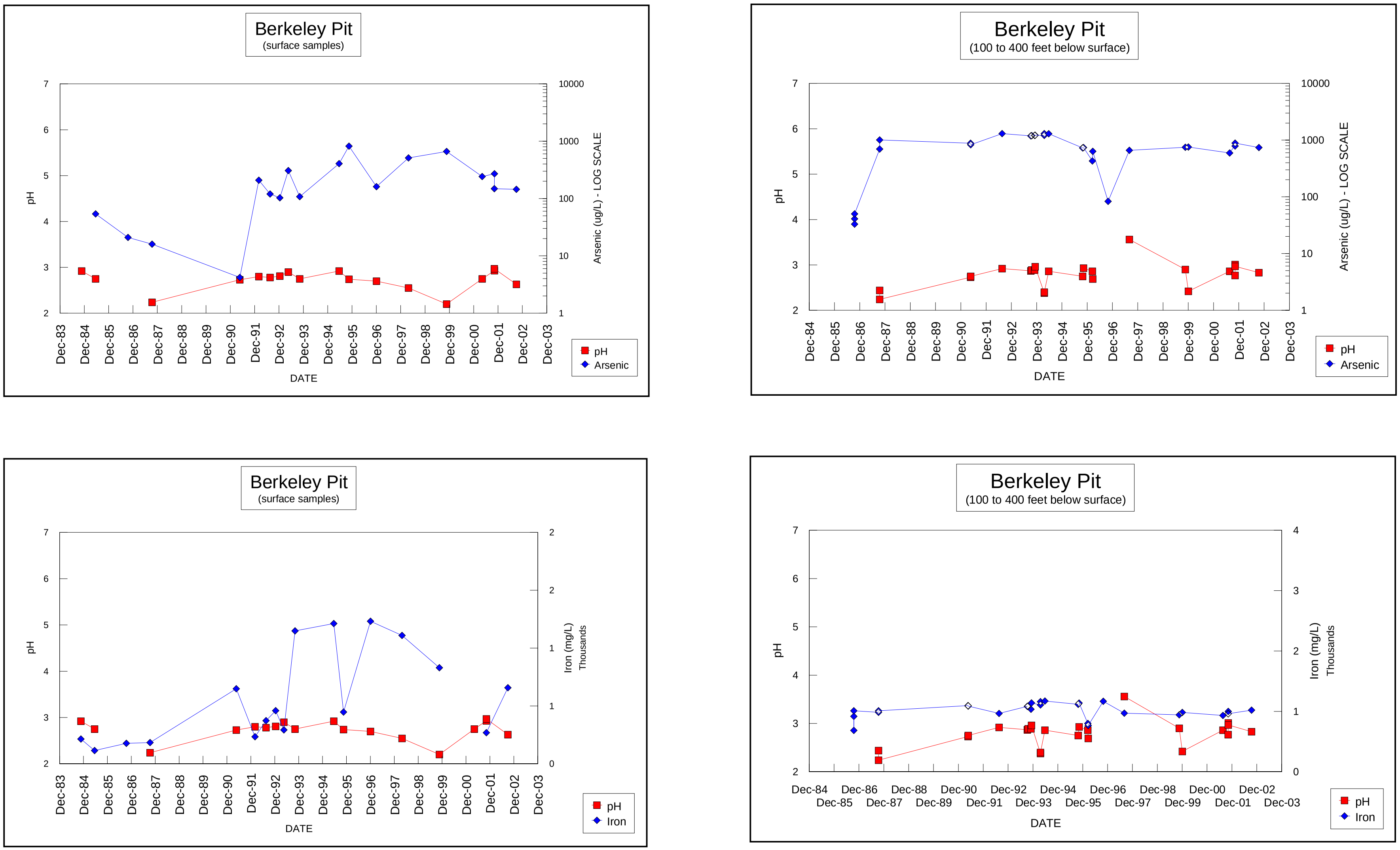


Figure 2-50b. Selected chemistry for the Berkeley Pit

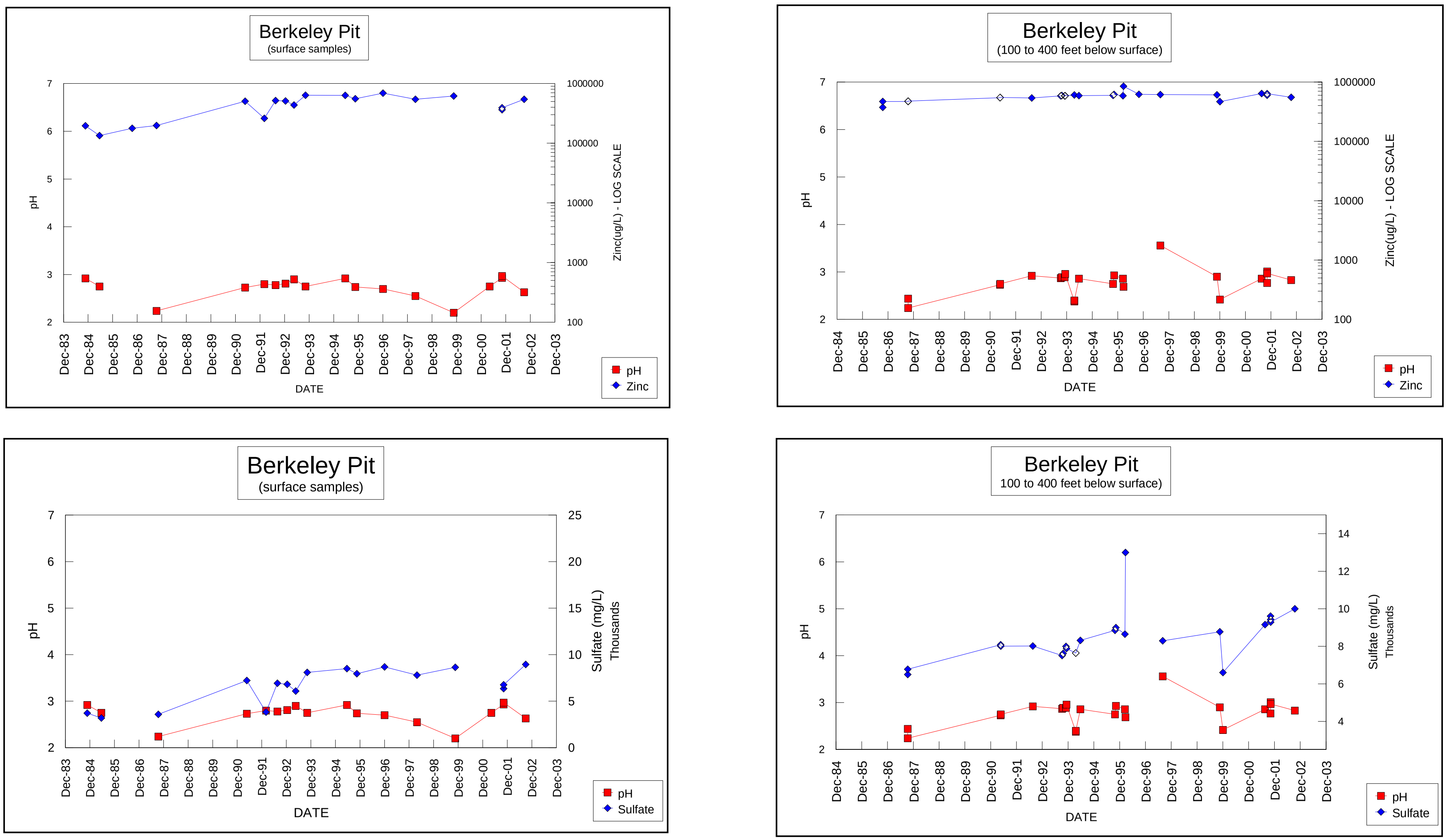


Figure 2-50c. Selected chemistry for the Berkeley Pit

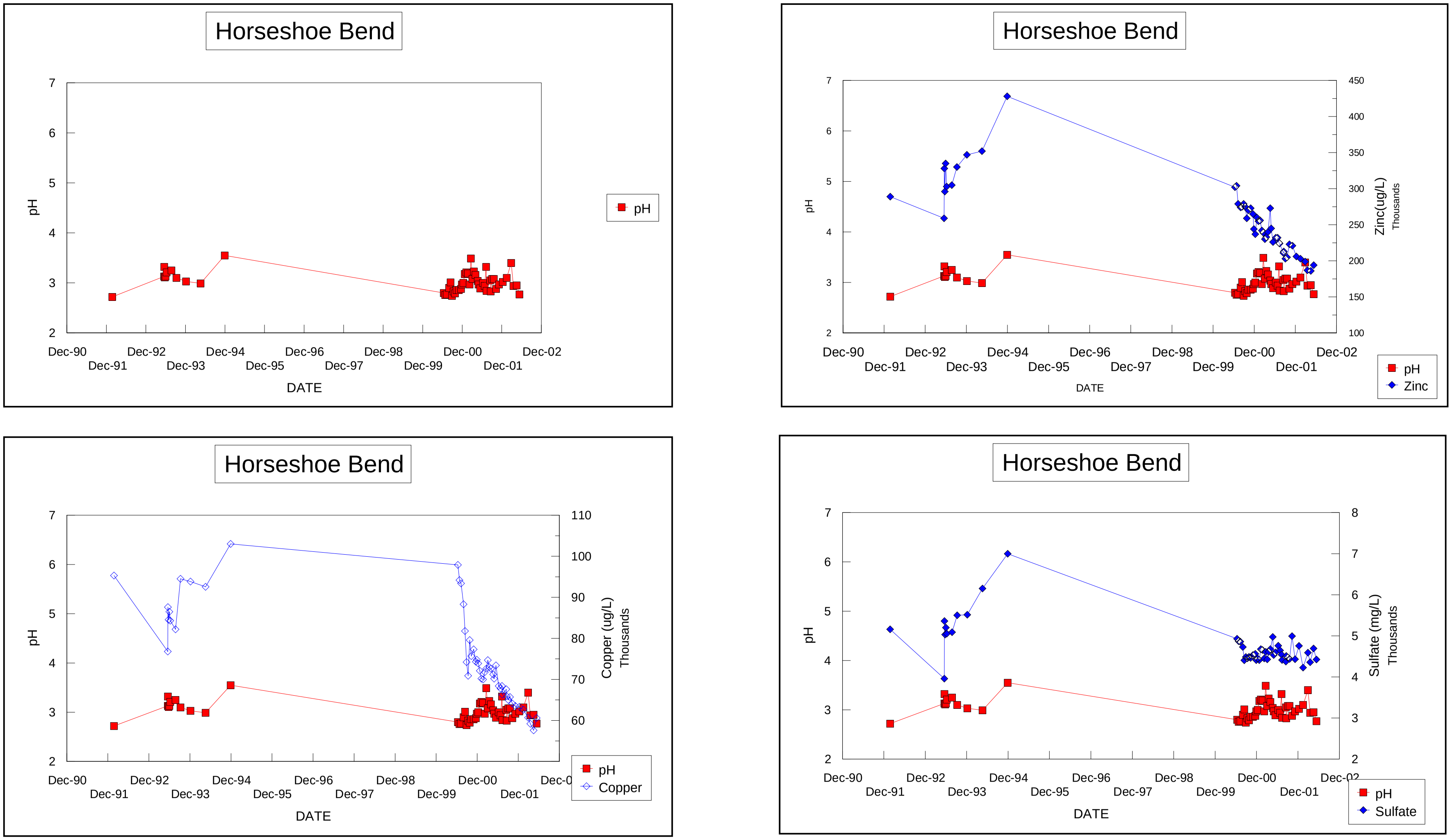


Figure 2-51. Selected chemistry for the Horseshoe Bend discharge.

Table 2.2.3.1 Selected chemistry from the Berkeley Pit and the Horseshoe Bend sampling site, 2002 data

Area	Sample Date	pH (S.U.)	Al (µg/L)	Cu (µg/L)	Pb (µg/L)	SO_4 (mg/L)	Zn (µg/L)
Berkeley	10/02/02	2.63	253,000	118,000	<100	8,950	545,000
HSB	11/21/02	3.09	118,000	52,400	<20	3,010	169,000
Sarsfield	10/14/02	6.67	<30	<5	<10	1,139	4,900
Continental	11/21/02	7.45	1,000	420	<10	1,310	3,860

SECTION 3.0 WEST CAMP SYSTEM

Water-level monitoring continued during 2002 in the mine shafts and six monitoring wells (figure 3-1). ARCO diverted the water pumped from the West Camp to the Lower Area One wetlands demonstration site during March 2002. As a result, pumping rates were reduced and water levels rose slightly for the year.

Section 3.1 West Camp Underground Mines

Water levels in the West Camp Mine system continue to be controlled by pumping facilities located at the BMF-96-1D and BMF-96-1S sites. ARCO had a special well drilled for dewatering (pumping) purposes in the fall of 1997. This well is referred to as the West Camp Pumping Well (WCP). Pumping activities were transferred from the Travona Mine to this site on October 23, 1998. The pump and pipeline at the Travona Mine were left intact, however, allowing it to serve as a backup pumping system.

The West Camp pumping system operated almost continuously during 2002, with the exception of several short periods caused by power outages and short periods for maintenance. However, the pumping rates were less than those of recent years. A total of 247 acre-feet of water was pumped in 2002, compared to 260 acre-feet in 2001, and 270 acre-feet in 2000. Table 3.1.1 shows the annual amount of water pumped in acre-feet on a yearly basis, percent change from the previous year, and the percent change from 1996 (the first full year of continuous pumping). Figure 3-2 shows the amount of water pumped annually and the percent of average annual precipitation since 1982.

Water-level changes in the West Camp mines reflect changes in pumping rates in the WCP. The reduced pumping rate resulted in a net water-level increase of over 1.25 feet in the West Camp mines for 2002 (table 3.1.2). Figure 3-3 shows annual water-level changes for the West Camp sites. Water levels are more than 10 feet below the West Camp action level of 5,435 feet stipulated in the 1994 ROD.

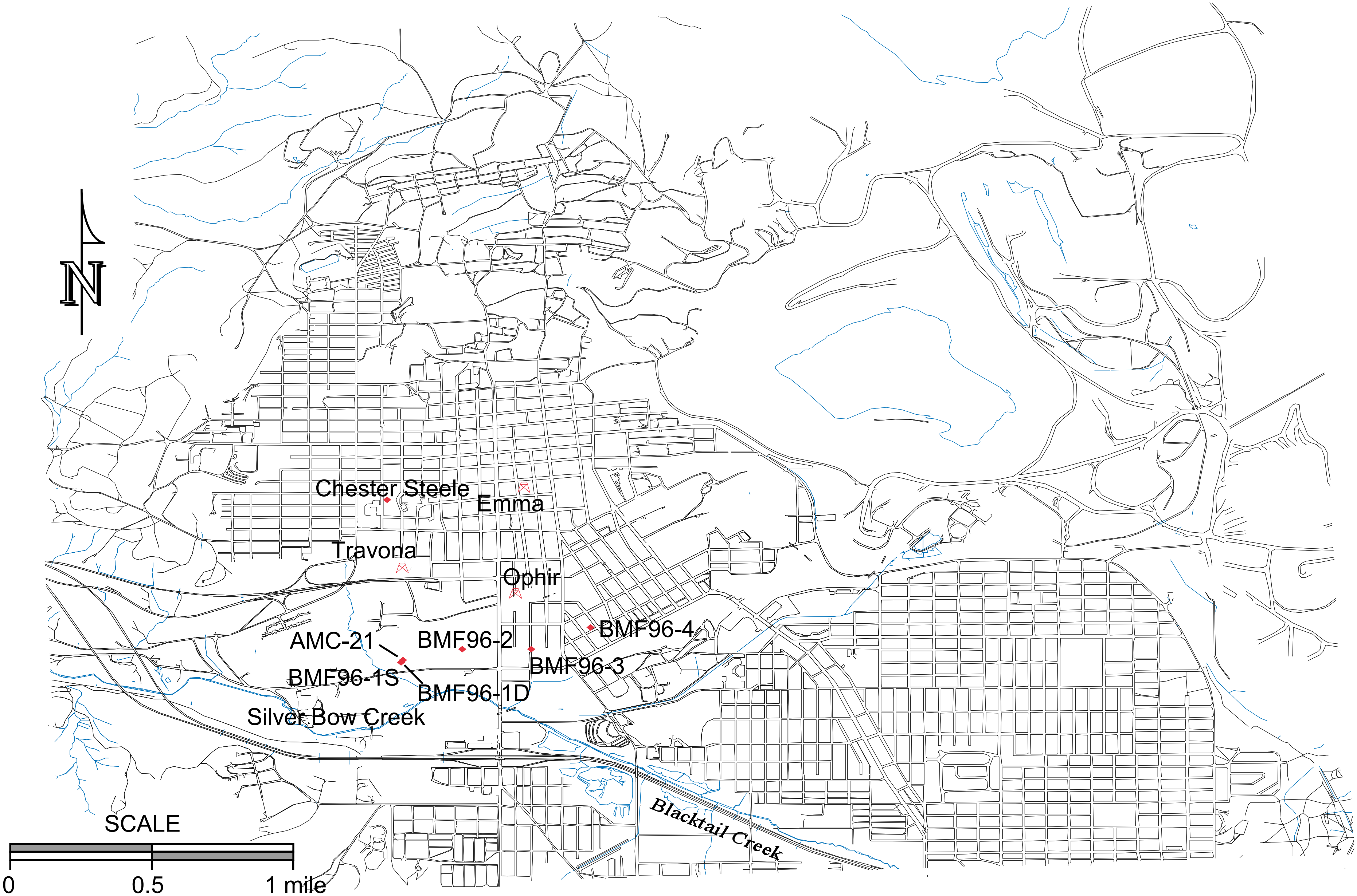


Figure 3-1. West Camp monitoring sites location map.

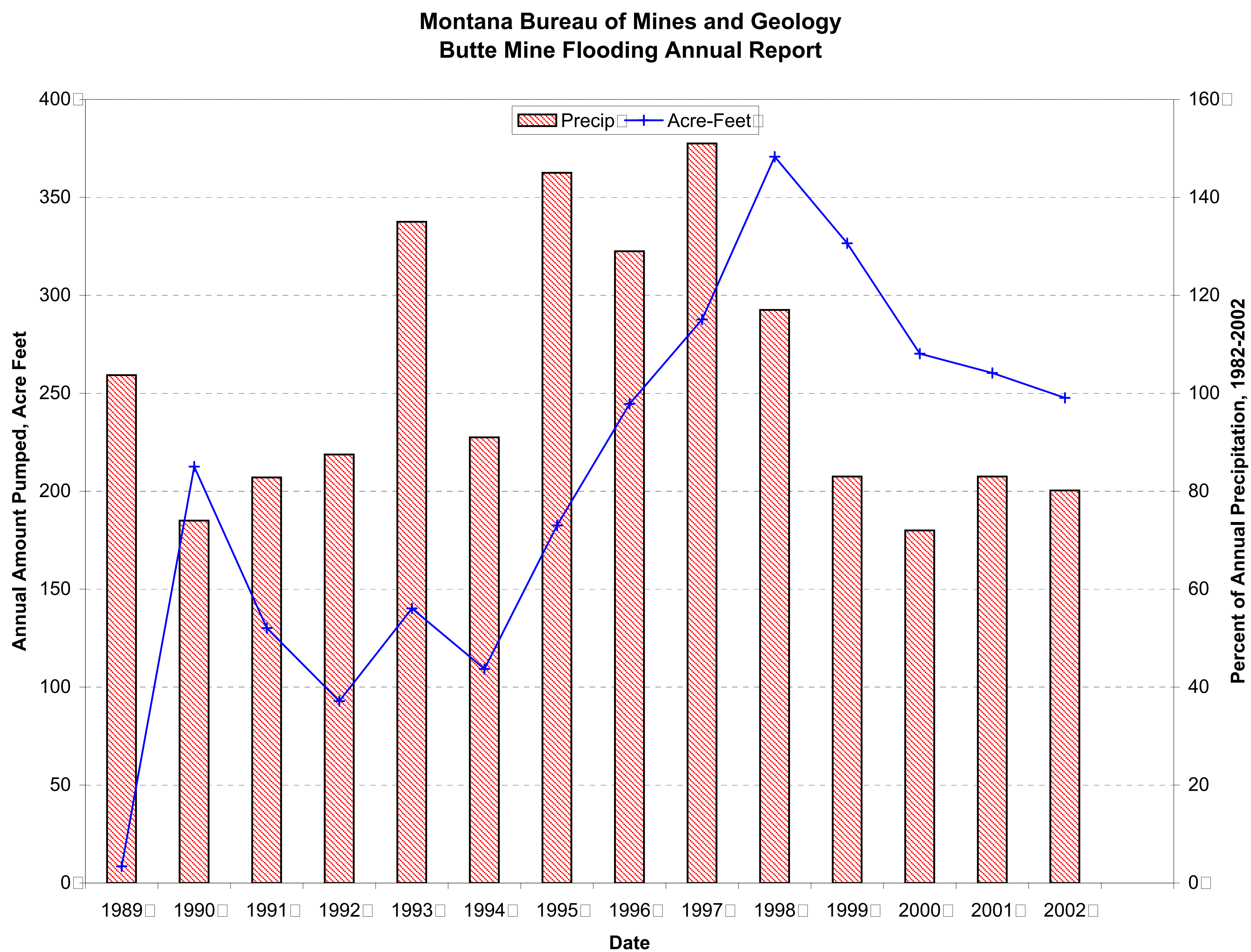


Figure 3-2. Annual amount of water pumped from the West Camp system.

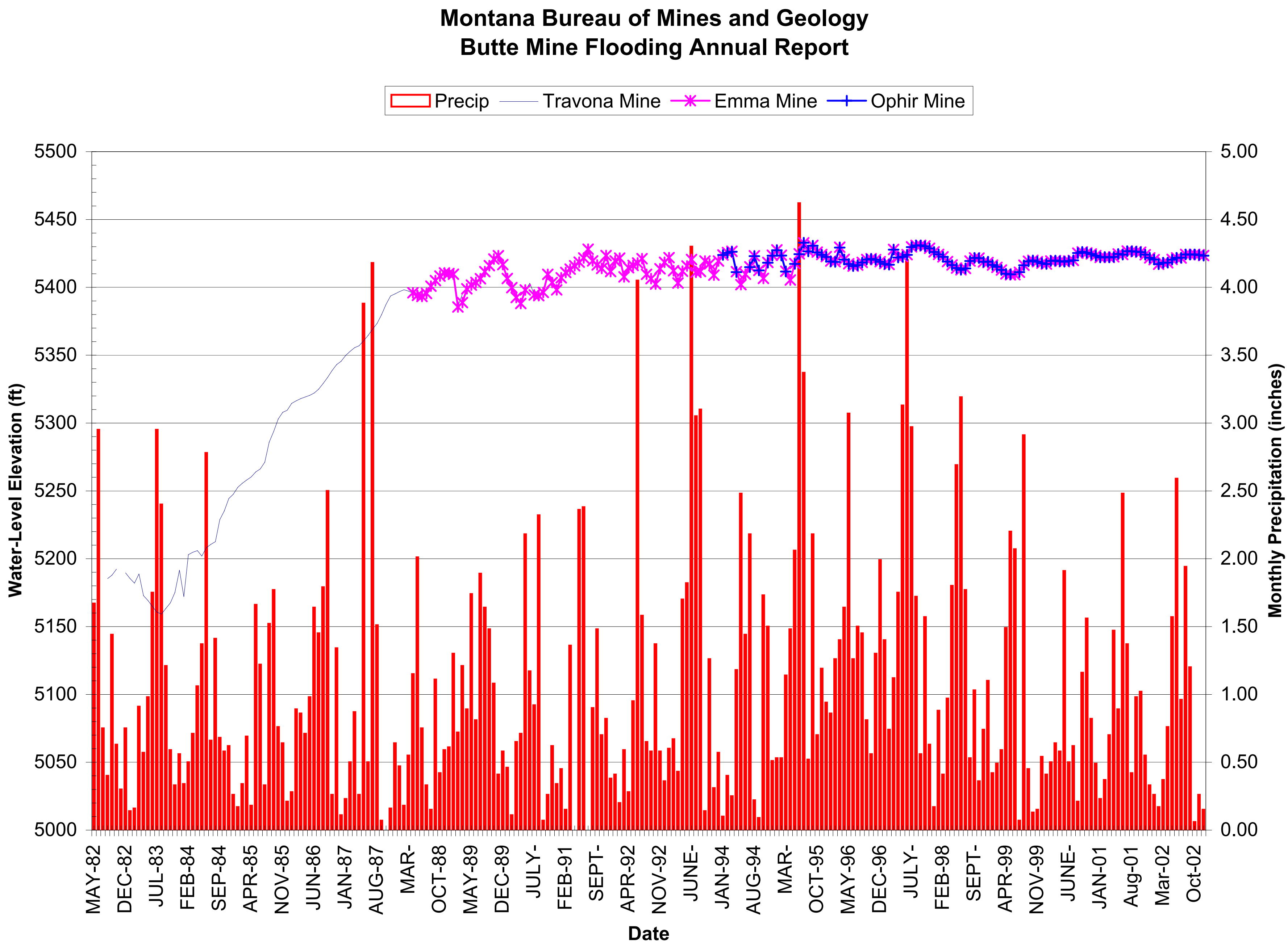


Figure 3-4. West Camp Mines water-level hydrographs and monthly precipitation totals.

Table 3.1.1 Annual Quantity of Water Pumped from the West Camp, in Acre-Feet

Year	Total Amount Pumped	Change From Prior Year	Percent Change from 1996
1989	8.50		
1990	212.54	+204.04	
1991	130.16	-82.38	
1992	92.82	-37.34	
1993	140.18	+47.36	
1994	109.31	-30.87	
1995	182.54	+73.23	
1996	244.56	+62.02	
1997	287.70	+43.14	118
1998	370.72	+83.02	152
1999	326.56	-44.16	134
2000	270.20	-56.36	110
2001	260.37	-9.83	106
2002	247.66	-12.71	101

Monthly water-level elevations for the three West Camp mines are shown on figure 3-4. Water levels in these mines are almost identical and continue to follow the trends of previous years. Pumping rates and the amount of water pumped are the most important controls on water levels.

Section 3.2 West Camp Monitoring Wells

Water levels rose in two of the five BMF96 West Camp wells during 2002, those being BMF96-1D and BMF96-1S. Well BMF96-1D, which was completed into the Travona Mine workings, had water-level changes similar to the three West Camp mines, rising over 2 feet. The water level in well BMF96-1S rose over 2.5 feet. These changes are shown in table 3.1.2 and on figure 3-3.

Figure 3-5 contains water-level hydrographs for wells BMF96-1D, BMF96-1S and BMF96-4. Water levels in wells BMF96-1D and BMF96-4 respond similarly to one another, reflecting the influence pumping has on the system. This is an important trend since well BMF96-4 was not completed into mine workings. It is, however, in the area of the historic 1960's flooding problems that led the Anaconda Company to install well AMC-21 for control of water levels in the West Camp. (See Duaime and others, 1998 for a greater discussion of historic flooding problems in the West Camp System). While water levels had a net decline in well BMF96-4, and a net rise in BMF96-1D in 2002, the overall trends in these wells were still the same. There is a lag time between the responses seen in these two wells, which is most likely because well BMF96-4 was not completed into mine workings. During periods of continued water-level change in wells BMF96-1D and BMF96-4, there appears to be a similarity in water-level change in well BMF96-1S. Well BMF96-1S is located adjacent to well BMF96-1D, but was completed at a much shallower depth in the weathered bedrock of the Missoula Gulch drainage. This well shows a response to pumping in the WCP. There was no change in longer-term trends in any of these wells from those described in the previous reports.

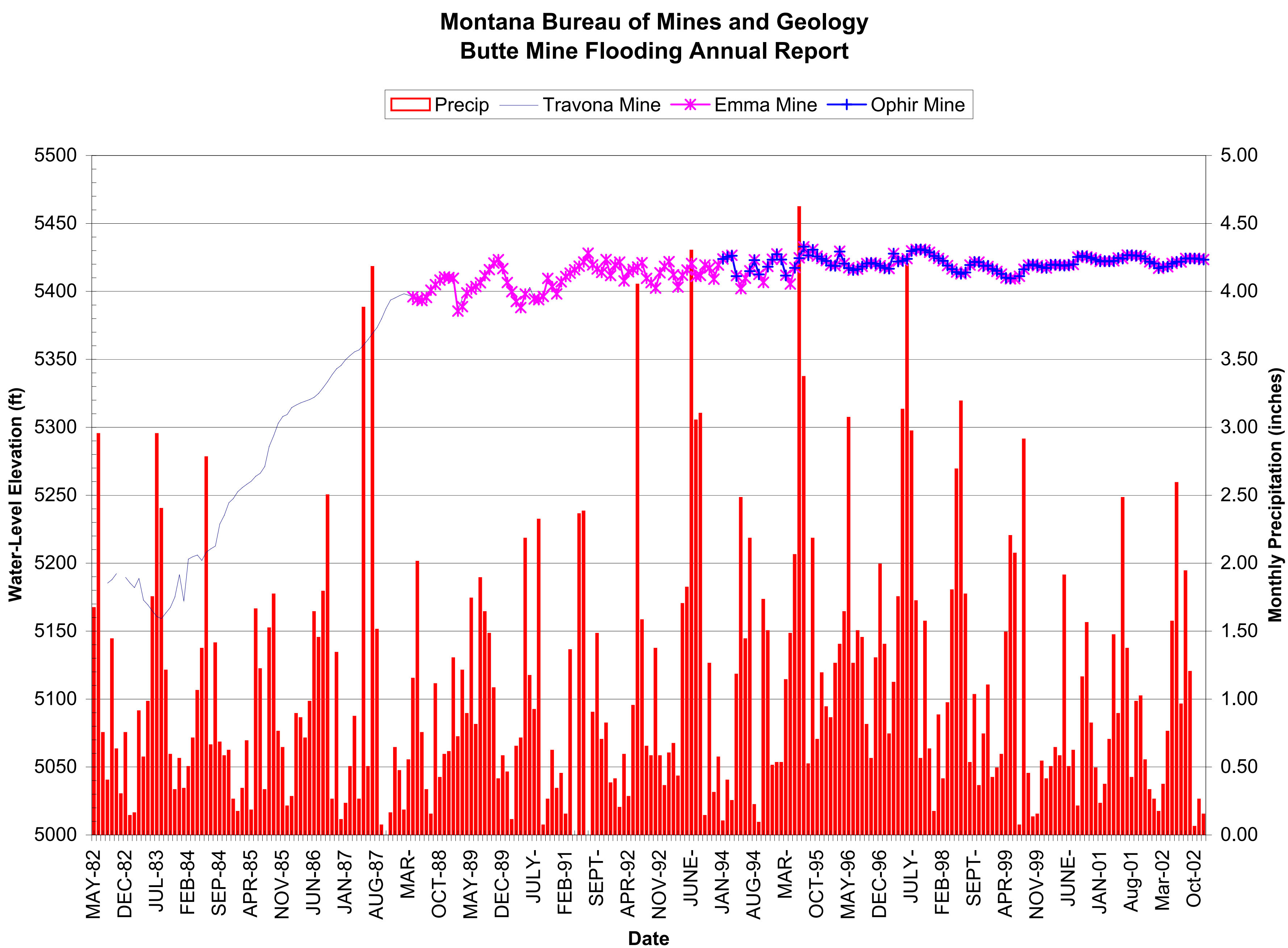


Figure 3-4. West Camp Mines water-level hydrographs and monthly precipitation totals.

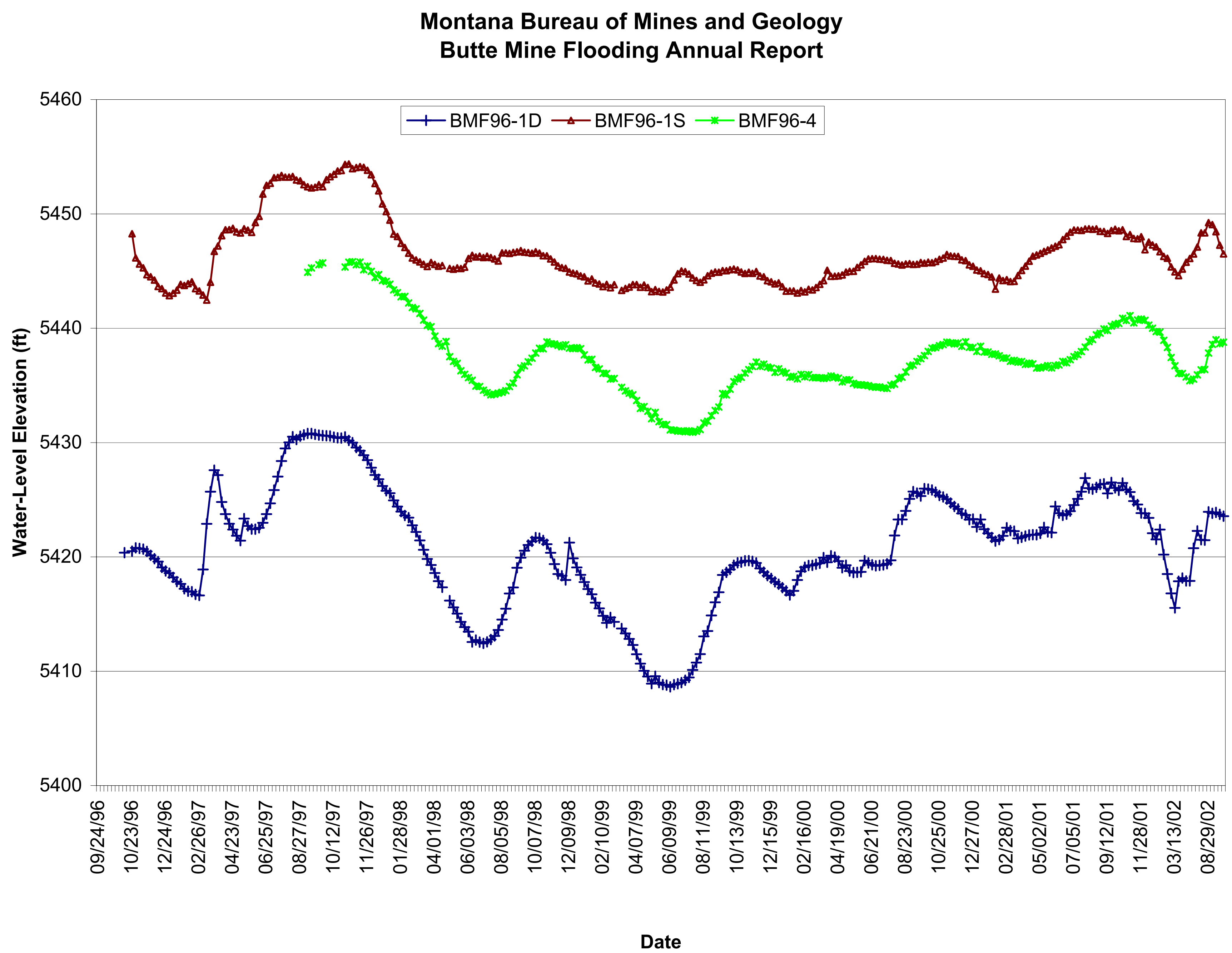


Figure 3-5. Water-level hydrographs for West Camp BMF96-1D, BMF96-1S, and BMF96-4 wells.

Water levels in wells BMF96-2 and BMF96-3 are 20 to 50 feet higher than those in wells BMF96-1D and BMF96-4, and when plotted with the other BMF96 wells, appear to show very little change (figure 3-6). However, when these wells are plotted separately (figure 3-7), there is considerable variation in monthly water levels, and water levels in both wells respond similarly. Monthly precipitation is shown on this figure and water levels are seen to respond very quickly to precipitation events. Although these wells were completed at depths of 175 feet below ground surface, their water levels are less than 20 feet below ground surface. Water-level trends during 2002 in these wells for the most part were similar to those seen in previous years. During the last half of 2001 an unexplained water-level increase of several feet occurred in well BMF96-2; this was not seen in other wells. This trend did not continue in 2002; the water level in well BMF96-2 followed that of well BMF96-3 throughout 2002. Water levels rose with precipitation, while showing an overall decline for the year.

Table 3.1.2 Annual Water-Level Changes for the West Camp Sites, in feet

Year	Travona	Emma	Ophir	AMC-21	Chester Steele	BMF 96-1D	BMF 96-1S	BMF 96-2	BMF 96-3	BMF 96-4
1982	4.30									
1983	2.00									
1984	55.90									
1985	61.90									
1986	36.10									
1987	49.70			33.48						
1988	15.69	14.20		14.32	16.42					
1989	5.67	6.60		6.52	1.79					
1990	-18.42	-18.66		-2.84	-5.77					
1991	13.88	13.52		7.57	-8.28					
Total 10-Year Change*	***226.72***	***15.66***		***59.05***	***4.16***					
1992	7.21	6.79		1.55	-11.20					
1993	1.01	0.93		2.71	-1.11					
1994	4.24	4.26	4.00	-0.78	5.36					
1995	-0.98	-1.00	-0.96	3.32	12.72					
1996	-3.72	-3.76	-3.56	-21.69	6.14	-1.50	-5.41	0.00	-2.85	
1997	7.29	7.28	7.22	11.66	14.82	7.20	7.36	2.13	-0.19	-0.80
1998	-7.31	-7.88	-7.20	NA	-2.51	-7.35	-5.63	-2.00	-0.26	-5.88
1999	-0.97	-0.47	-1.03	NA	-5.37	-0.82	-0.61	-1.15	-0.38	-1.76
2000	5.56	5.61	5.53	NA	-4.64	5.70	1.45	-1.13	-0.07	1.86
2001	-1.65	-1.70	-1.52	NA	15.61	-1.78	1.70	3.23	0.10	1.40
2002	1.33	1.74	1.51	NA	-6.35	2.03	2.66	-2.06	-0.21	-0.93
Total Change*	***238.73***	***27.46***	***3.99***	***55.82***	***27.63***	***3.48***	***1.52***	***-0.98***	***-3.86***	***-6.11***

(*) Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

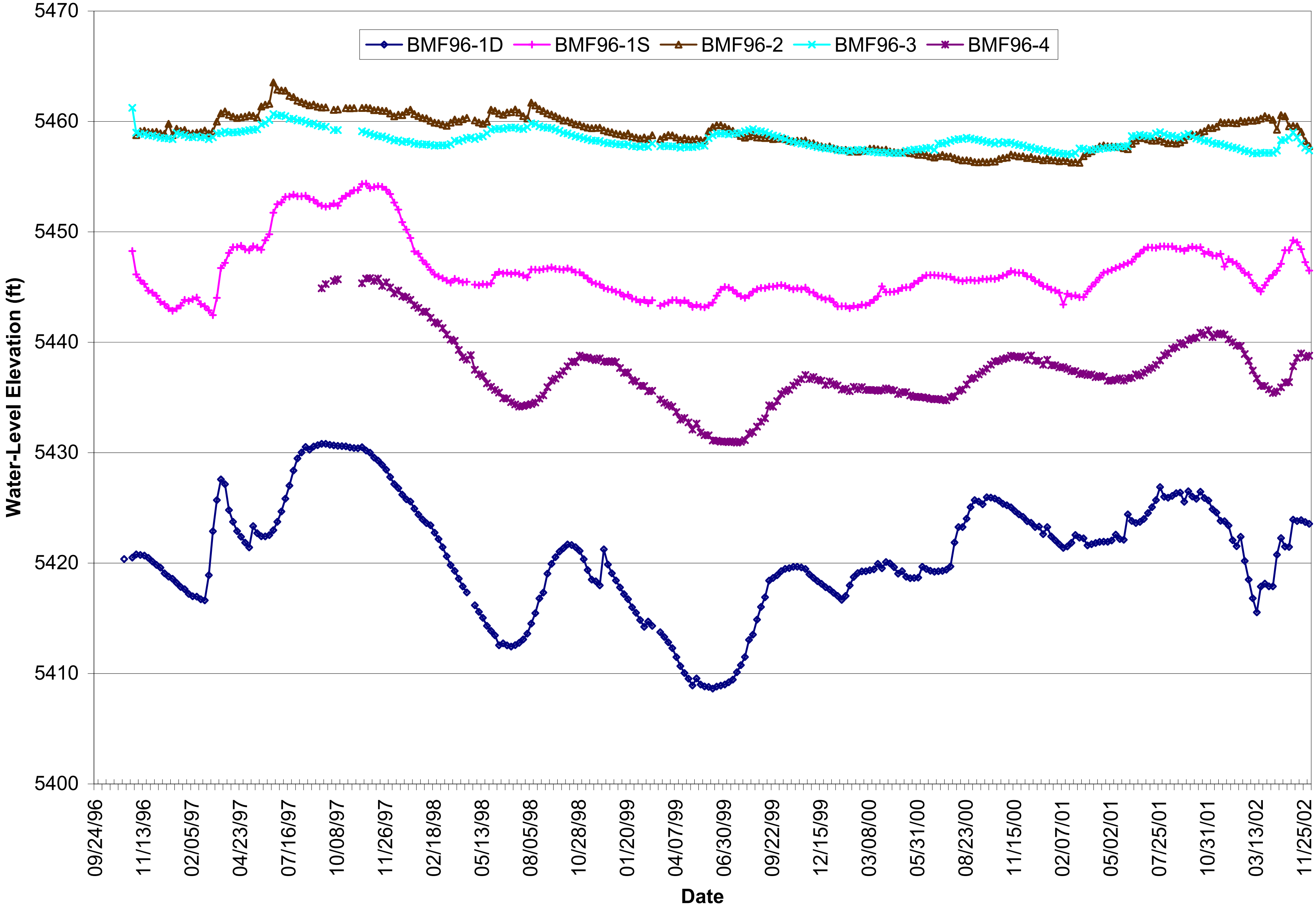


Figure 3-6. Water-level hydrographs for BMF96 series wells.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

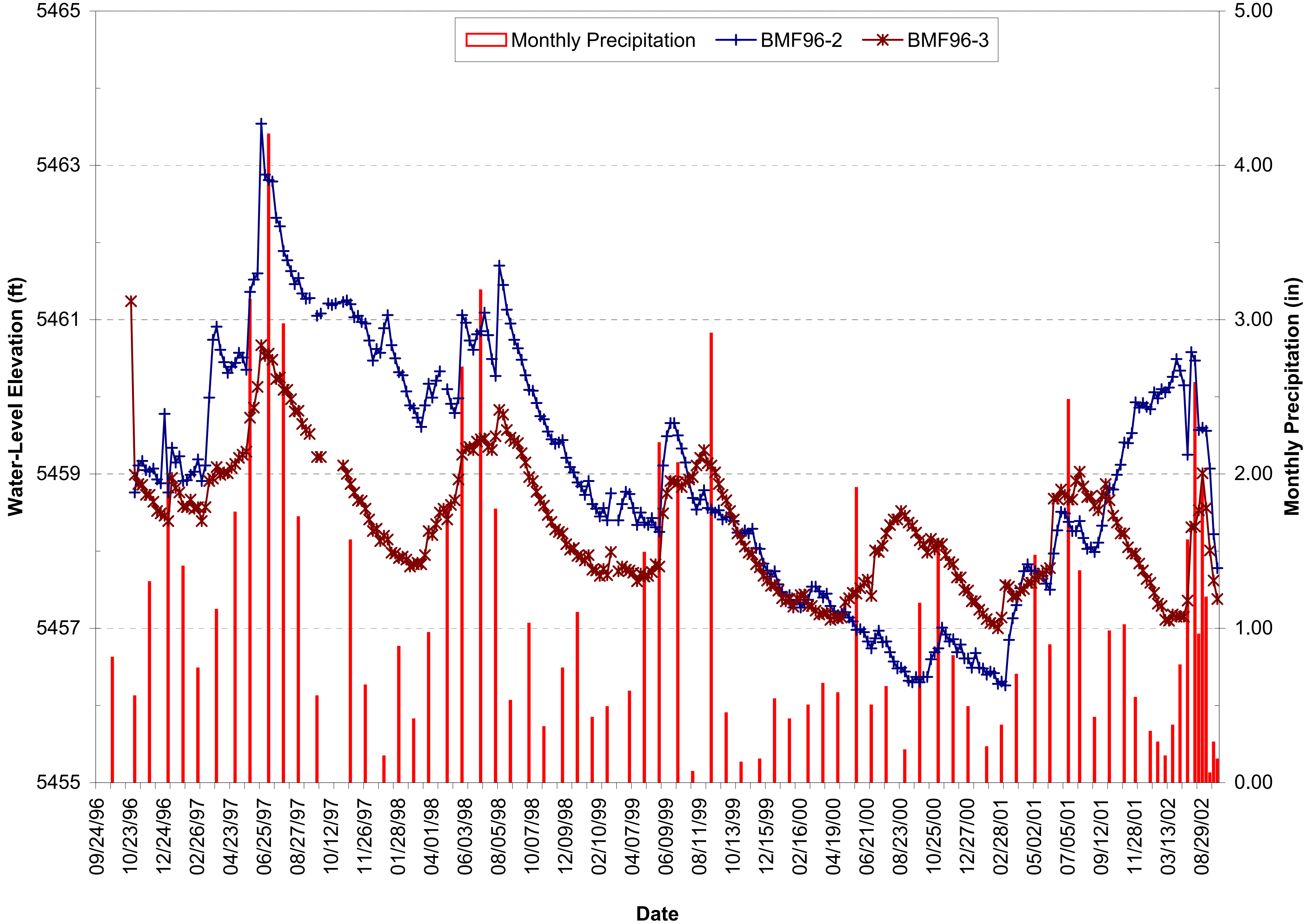


Figure 3-7. Water-level hydrographs for BMF96-2 and BMF96-3 wells.

Section 3.2.1 West Camp Mines and Monitoring Wells Water Quality

Water-quality trends in the Travona Mine, as monitored from the replacement well BMF96-1D, have not varied to any great extent in the past few years. The arsenic concentration has increased in 2002 compared to previous data and continues to suggest an upward trend, especially since constant pumping of the well began in 1996. The concentration of manganese, zinc, and sulfate continue to decrease and are approaching the lowest concentration within the period of record.

The most recent data from the Emma shaft, which is connected to the Travona Mine by workings at several levels, indicate a large departure from recent water-quality trends. Moreover, the most recent data suggest a large departure from what was formerly similar chemistry in the two mines. Zinc concentrations were reported at 39,500 µg/L for 2002; concentrations for the past two years were 5,500 and 1,300 µg/L. Cadmium concentrations in 2000 and 2001 were 9.8 and less than 1.1 µg/L, respectively; 2002 data indicated a concentration of about 87 µg/L — well above the MCL of 5 µg/L. Sulfate concentrations have not changed appreciably over the past few years; 2002 data did not indicate a significant change. Iron decreased from about 5 mg/L in 2001 to 0.22 mg/L in 2002. Figure 3-8 presents a comparison of selected dissolved constituents for the Travona / BMF96-1D and the Emma shaft. As with other results of the 2002 sampling, the authors are cautious to call these true changes until more data have been collected.

Water-quality data were not collected from the Ophir shaft in 2002 due to problems with the sampling pump. To maintain consistency, the previous year's evaluation of water quality is repeated here. The concentration of dissolved metals in the Ophir Mine has remained relatively low and consistent throughout the period of record (1994 to 2001), especially compared to the Travona and Emma Mines. Arsenic and sulfate concentrations, however, have fluctuated and indicate change. The concentration of arsenic has decreased from about 40 µg/L to less than 10 µg/L; most recent data indicate a slight increase to about 15 µg/L (figure 3-9). Sulfate concentrations have ranged from 400 to 600 mg/L; the most recent data indicate a decrease to about 200 mg/L (figure 3-9). Data for the West Camp monitoring wells are presented in figure 3-10.

Section 3.3 Controls on Water Chemistry in the Travona Mine

Section 3.3.1 Background

The Travona Mine is reportedly the oldest hardrock mine in the Butte Mining District. A major silver discovery in 1875 led to about 18 years of silver production from the area. After several years of inactivity, the mine was re-opened for its wealth of "zinc-free" manganese ore (rhodochrosite) as well as minor reserves of silver. As the mine expanded, many of the workings

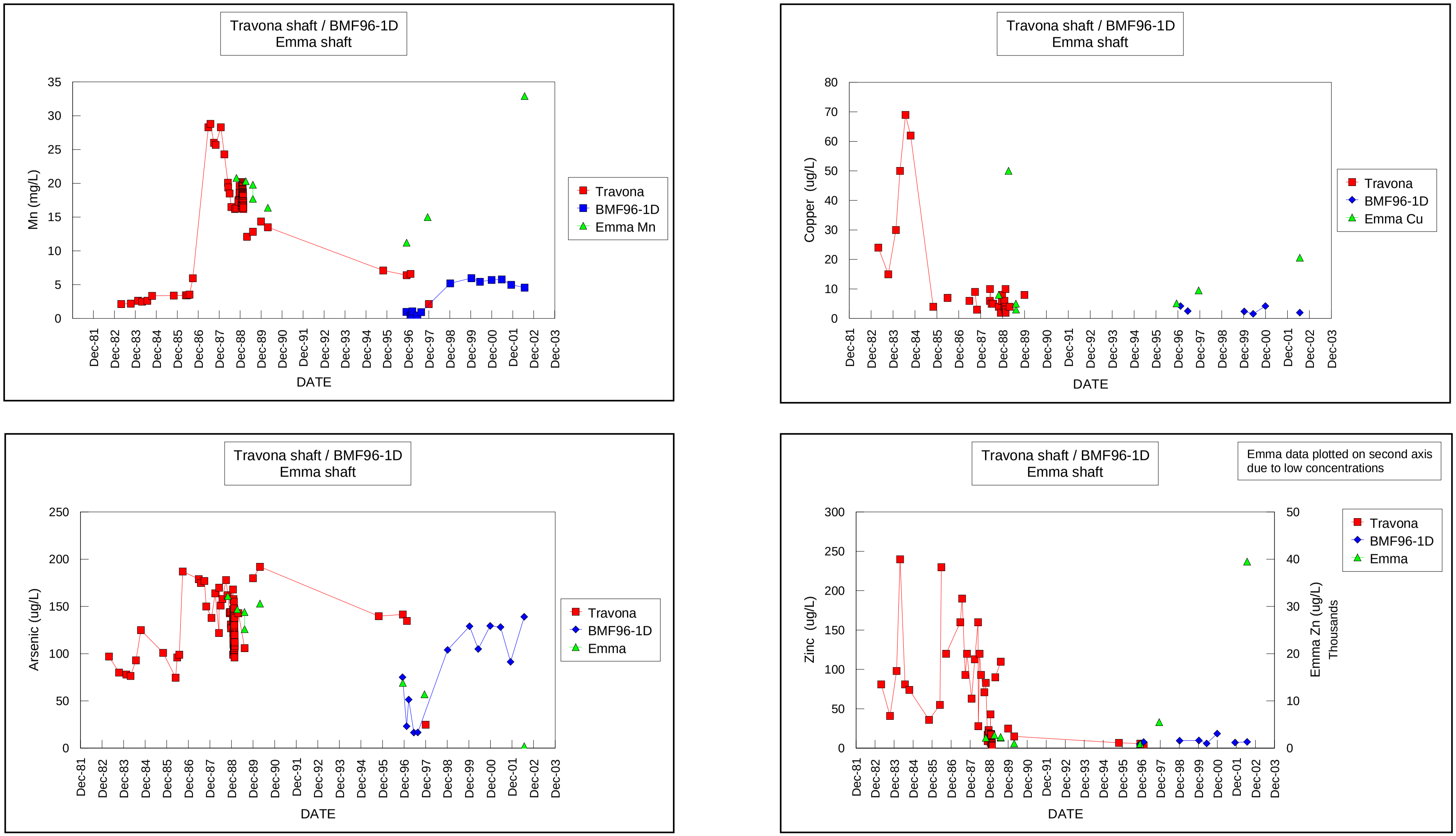


Figure 3-8a. Selected chemistry for the Travona shaft (and replacement well) and the Emma shaft

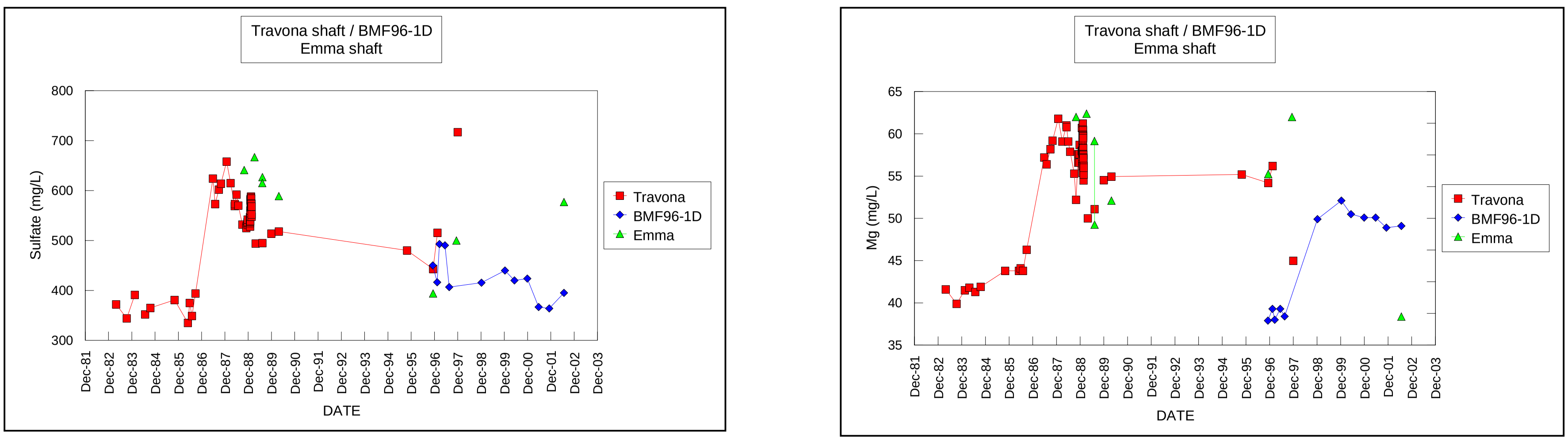
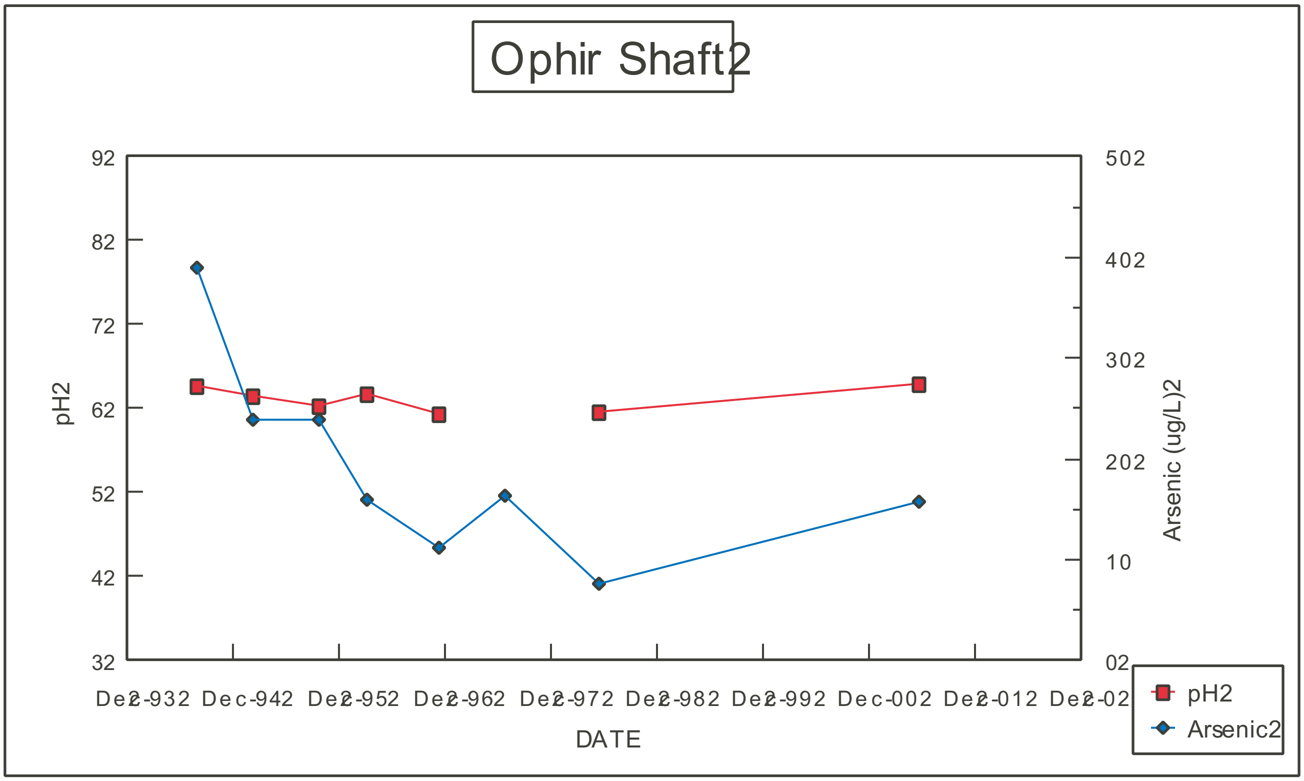


Figure 3-8b. Selected chemistry for the Travona shaft (and replacement well) and the Emma shaft.



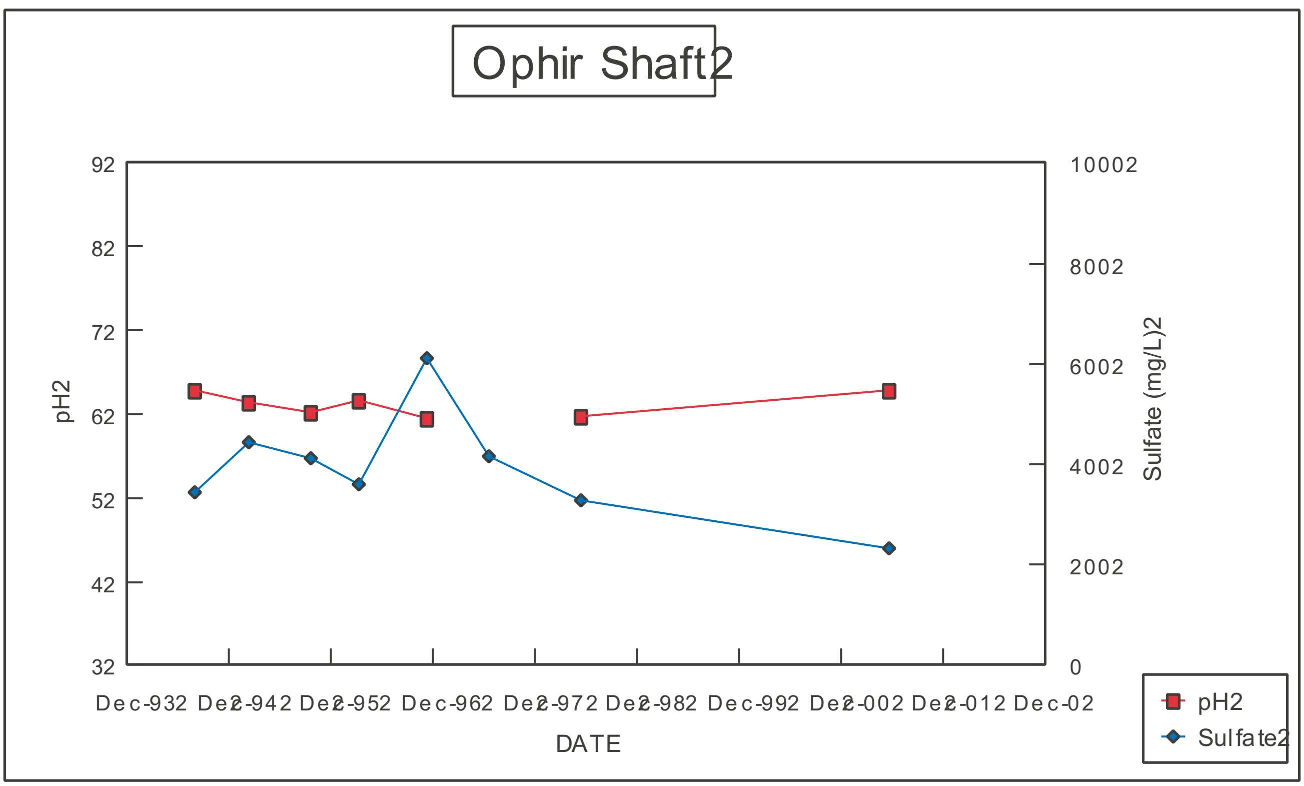


Figure 3-9. Arsenic and sulfate trends for the Ophir Shaft2

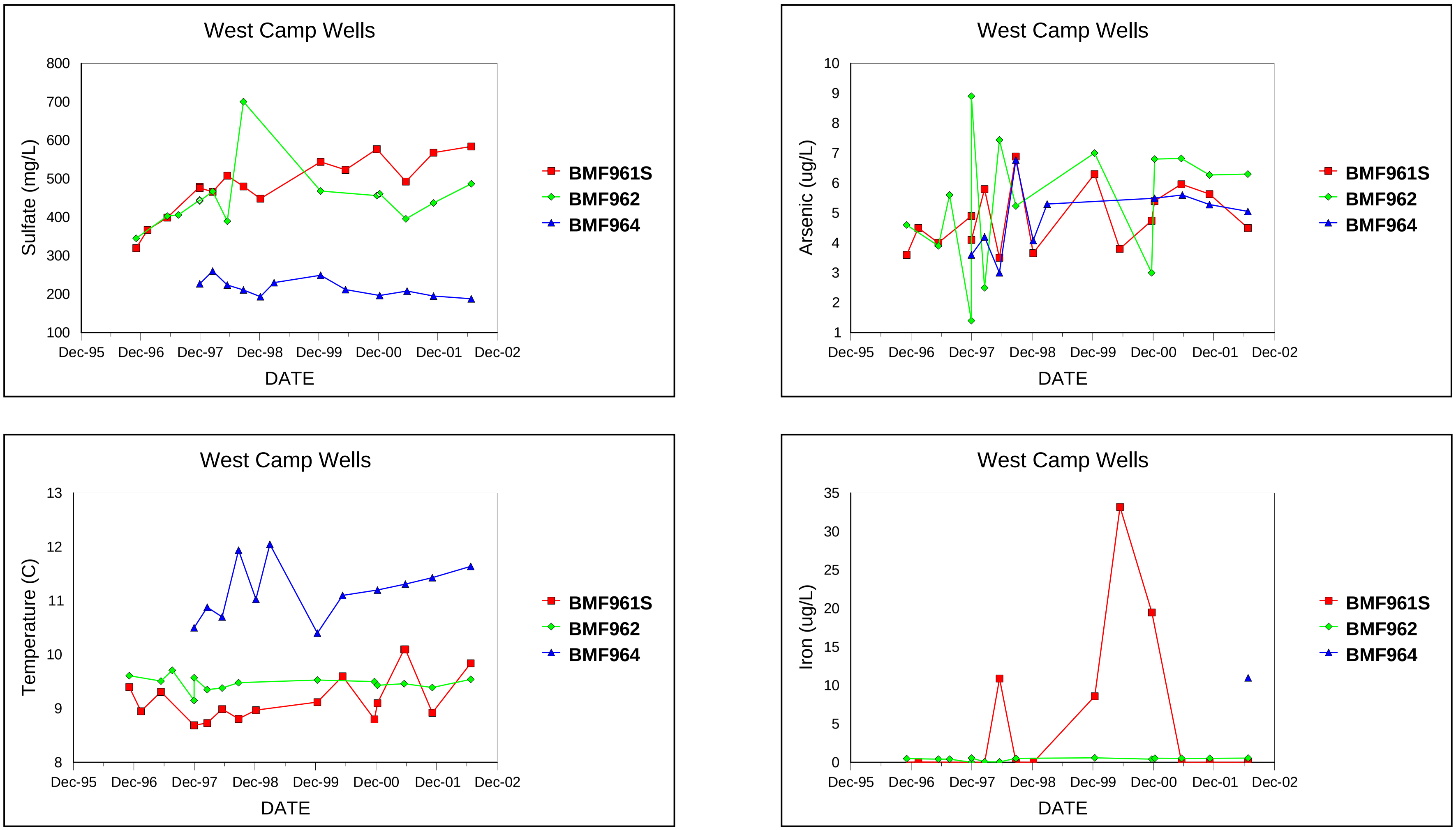
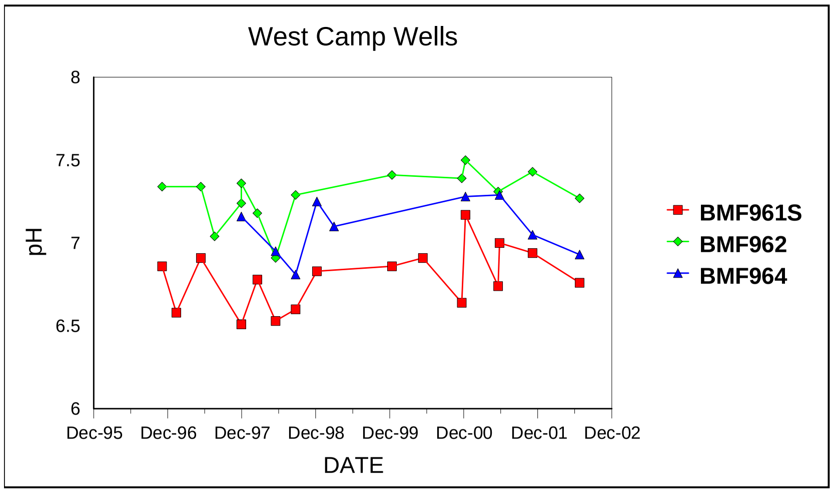


Figure 3-10a. Selected chemistry for the West Camp monitoring wells.



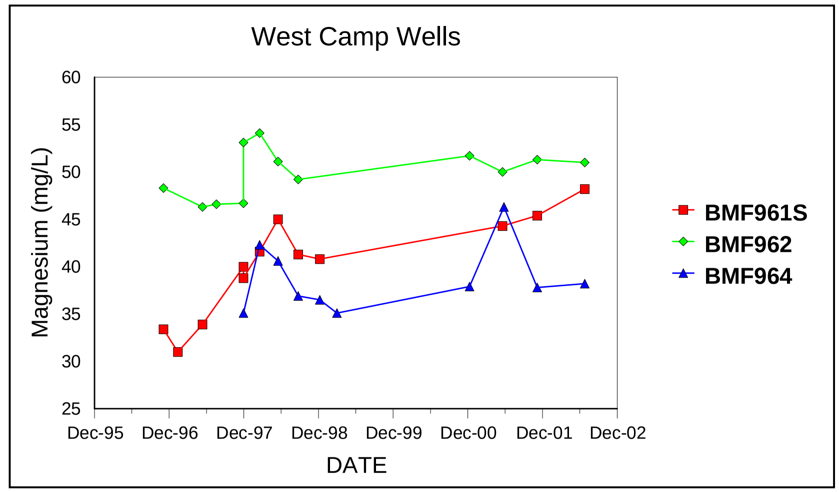


Figure 3-10b. Selected chemistry for the West Camp monitoring wells.

of the Travona intersected those of the Emma and Ophir Mines to the east, and were commonly referred to as the West Camp mines. When mine ownership in the Butte District was consolidated, several of the workings were extended to the East Camp mines including the Steward and Belmont Mines, north and east of the West Camp (figure 3-11).

Ore production from the West Camp had all but ceased by 1960; dewatering ended in 1965. The workings were separated from those of the East Camp (Steward and Belmont Mines) by water tight bulkheads (figure 3-11); the intent was to reduce the amount of pumping that was required to keep the workings of the East Camp dry and allow flooding of the West Camp. Water levels in the West Camp rose until springs developed at the surface in residential areas downhill of the mines. A relief well was drilled into the workings in 1966 to drain the mine water directly to Silver Bow Creek; initial discharge from the well was estimated to be 3,800 gpm. Flow from the well declined over several months and eventually stopped.

Although the workings of the West Camp were bulkheaded, there remains at least some hydrologic connection to the East Camp. This is evidenced by the response in water levels during the final flooding of the mines. When all pumping from the Butte mines ceased in April of 1982, the initial data showed that there was little effect on water levels in the Travona shaft. However, about 15 months after the East Camp began to flood, water levels in the Travona shaft began to rise (figure 3-12); initially, the water level in the Travona was about 2,200 feet higher than mines of the East Camp. By 1985, there was an 850-foot difference in water levels between the West and East Camps; the rate of rise in the East Camp had slowed to about 10 feet per month and the rate of rise in the Travona was about 5 feet per month. Water levels in the West Camp have been controlled by pumping since 1989; concern for discharge to the surface and Silver Bow Creek prompted the establishment of an “action level” elevation of 5435 (amsl) above which the water level would not be allowed to rise.

Ground water and water within the workings of the Travona and Emma Mines exhibit higher water levels than any of the other mines in the district. This was particularly true after 1965 when the mine was allowed to flood. Although the hydraulic gradient from the West Camp to the East Camp has decreased since flooding of the East Camp began in 1982, there was still over 200 feet of head difference in 2002. Thus, the West Camp mines represent a system that is hydrologically isolated with respect to other mines in the district and is a potential source of ground-water recharge to the East Camp mines.

Section 3.3.2 Mineralogy

The Travona, Emma, and Ophir Mines exploited the southwest-northeast Emma vein system, which represents the southern extent of the large east-west vein system of the Butte Mining District. The vein mineralogy grades from oxide and carbonate ore minerals of the Peripheral

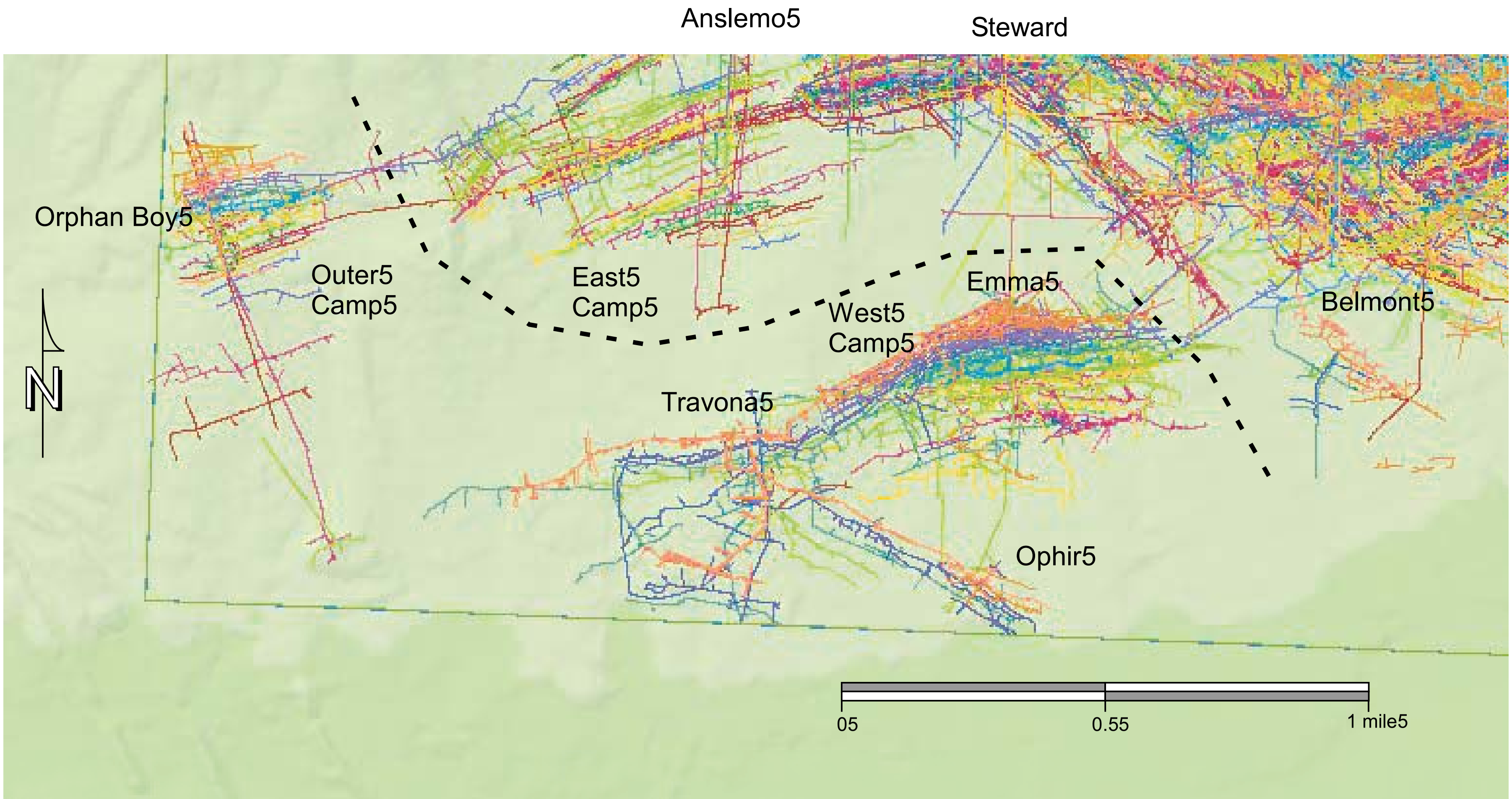


Figure 3-11. Composite map of mine workings in the West Camp (Travona, Emma, and Ophir mines) and East Camp (Belmont,5 Steward, and Anslemo mines); dashed line indicates approximate boundary. The Orphan Boy mine is considered part of the5 Outer Camp.5

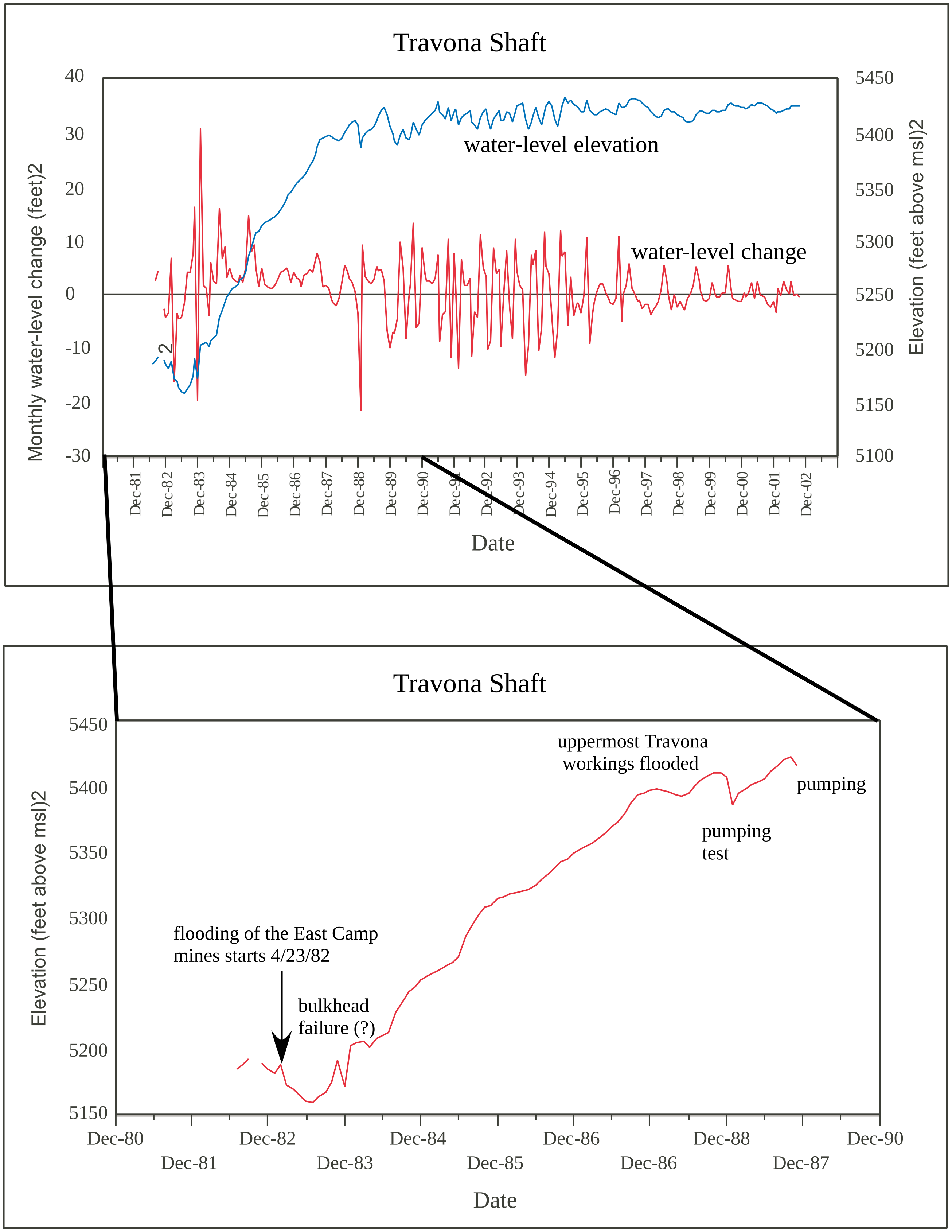


Fig 3-12. Water levels in the Travona shaft responded to flooding of the East Camp mines after2 a 15 month delay. Water levels have been controlled by pumping since 1989. The2 hydrograph forthe early period of flooding is expanded to show the effects of various2 events.2

Zone on the southwest end to sulfide minerals in the Intermediate Zone on the northeast end. The southwest end of the vein and mine workings is bounded on all levels by a post-mineralization rhyolite dike. Sales (1914) first described this area as being within the Peripheral Zone with rhodochrosite ($MnCO_3$), sphalerite (ZnS), and quartz (SiO_2). Zeihen (1986) revisited several of the mines in Butte and described them in more detail. The upper levels of the Emma vein system were found to contain rhodochrosite and quartz, minor pyrite (FeS_2), and minor sphalerite. The lower levels and eastern levels (Ophir) exposed veins of more sphalerite (sometimes coated with greenockite [CdS]) and minor chalcopyrite ($CuFeS_2$). Oxidized zones contained siliceous manganese oxides such as pyrolusite (MnO_2) and cryptomelane (KMn_8O_{16}). Alteration minerals in the Emma vein system are related to mild sericitic alteration (muscovite [$KAl_2(AlSi_3O_{10})(OH)_2$]), as well as kaolinite ($Al_2Si_2O_5(OH)_4$) and montmorillonite (($(Al,Mg)_8(Si_4O_{10})_3(OH)_{10} \bullet 12H_2O$), reflecting argillic alteration.

Section 3.3.3. Water Quality

Regular water-quality monitoring of the Travona Mine began in 1982, just after flooding of the East Camp mines began. In the early period of monitoring, samples were obtained by means of a bailer lowered down the shaft. In February of 1989, the Montana Bureau of Mines and Geology conducted a 28-day pumping test during which both water levels and water quality were monitored; samples were collected from the pump discharge. As noted, water levels in the West Camp have been controlled by pumping since 1989; samples have been collected from the pump discharge since that time. Analyses of samples usually included major anions, cations and dissolved metals.

In the first four years of flooding (1982 to1986) there was little change in the concentration of dissolved constituents; the pH was near neutral and dissolved metals concentrations were generally low (water levels had risen about 180 feet over that same period). Between July 1986 and July 1987, concentrations of several dissolved constituents including manganese, sulfate, and iron increased sharply (figure 3-13). After the peak in mid-1987, concentrations trended downward for the rest of the period of record interrupted only by the effects of a month-long pumping test in early 1989 (figure 3-13).

Section 3.3.4 Equilibrium Modeling: Travona Shaft

A geochemical equilibrium model, PHREEQE (Parkhurst, 1995), was used to evaluate those processes responsible for the changes in chemistry during the flooding of the Travona Mine. Minerals indigenous to the Travona, Emma, and Ophir Mines (table 3.3.4.1) were equilibrated with water whose chemistry represented ground waters entering the mines. Oxidation-reduction potential and the concentration of dissolved gases (CO_2 and H_2S) were varied within ranges based on measured values until calibration with measured concentrations was achieved.

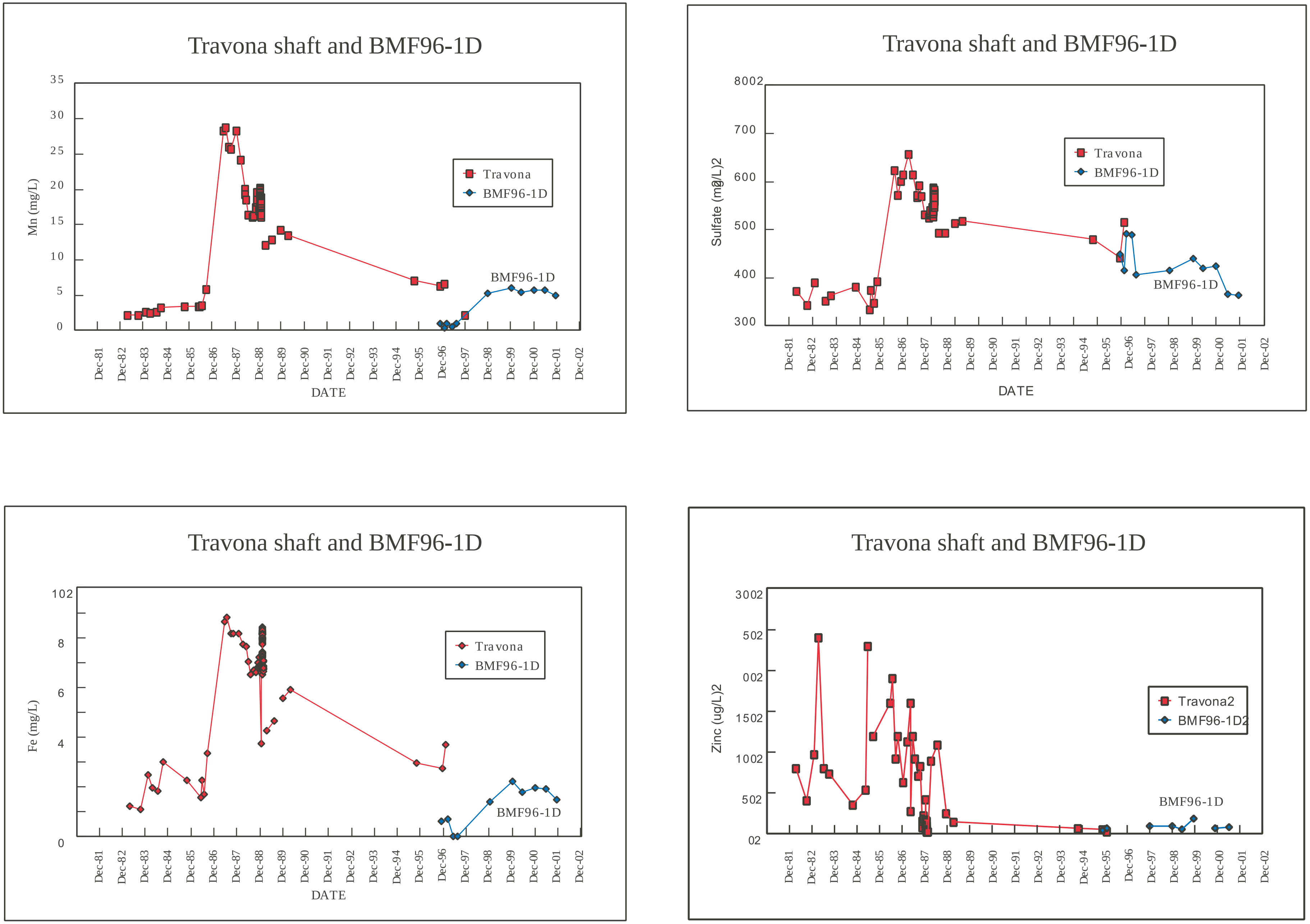


Figure 3-13. The concentration of manganese, sulfate, and iron increased dramatically in 1987 while that of zinc decreased.2 BMF96-1D is a well drilled into the workings of the Travona mine.2

Although concentration data from shallow monitoring wells vary with time and space, the change has been small; therefore, water quality of the ground water recharging the mine was assumed to be constant.

The relative amount of each mineral phase was controlled by specifying the saturation index and the mole-amount of each phase present. All of the mineral phases listed were used throughout the simulation.

Modeling focused on three time segments of the Travona flooding as related to the three significant changes in chemistry:

- early flooding (1984 to 1986),
- a period of rapid increase in concentrations of several dissolved constituents (1986 - 1987), and
- the relatively gradual decrease in concentrations (1989 to 2002).

Section 3.3.4.1 Early Flooding, 1984 to 1986

Preliminary modeling of the early-time segment suggested a lack of available iron for related reactions. Saturation indices indicated that under the conditions observed, the water was undersaturated with respect to all iron species. In other words, all the available iron from ground water flowing into the workings and all of the iron produced from dissolution of the available minerals failed to produce sufficient concentrations of iron in the final solution. Thus, only pre-existing soluble iron minerals could produce sufficient concentrations of iron. With respect to modeling, two alternatives were considered: 1) assume sufficient quantities of secondary, soluble, iron-rich minerals exist and add these to the list of minerals for equilibration, or 2) reproduce conditions found in the initial flooding of the workings using the same list of known minerals and inflow chemistry. The second alternative provides the best opportunity for a unique solution by limiting the assumptions regarding mineralogy and redox conditions. Also, water-chemistry-data collected during initial flooding of other sites in the area provides a reliable basis for pre-historic conditions in the Travona.

Pre-historic conditions in the Travona shaft were simulated by equilibrating the minerals listed in table 3.3.4.1 with water entering from the shallow leached zone. Each step of the model was considered a time step in the flooding of the mine. Oxygen was added to the modeled system in increasing amounts until the solution became acidic; oxygen was then added to the system in decreasing amounts until no oxygen was being introduced. All other inputs to the model were held constant throughout the simulation.

Figure 3-14a presents the results of the oxidation model for total iron and pH. The maximum iron concentration of about 1E-2 moles/L is in the lower range of concentrations observed at mines of the East Camp during initial flooding. The non-symmetrical nature of iron concentrations is evident when compared to pH (figure 3-14b). Iron concentration and pH coincided with observed values at

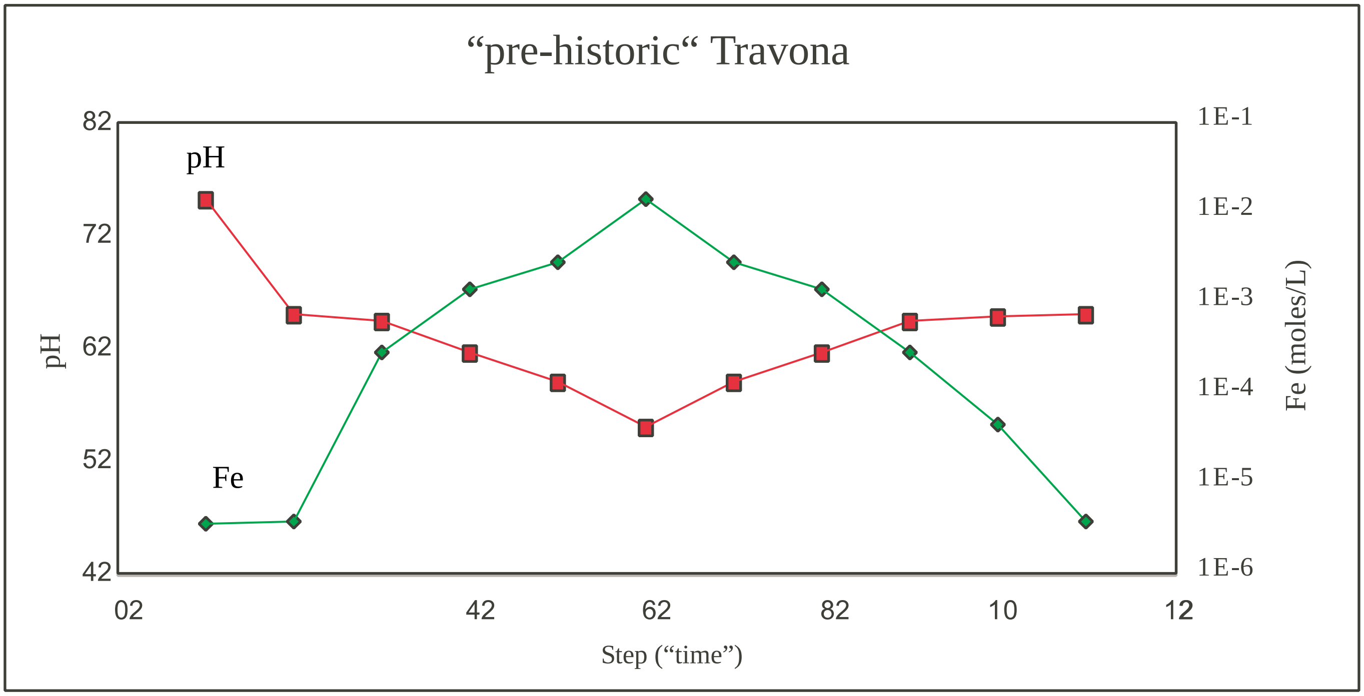


Figure3-14a. Model results for iron and pH as a function increasing and then decreasing2 oxygen. 2

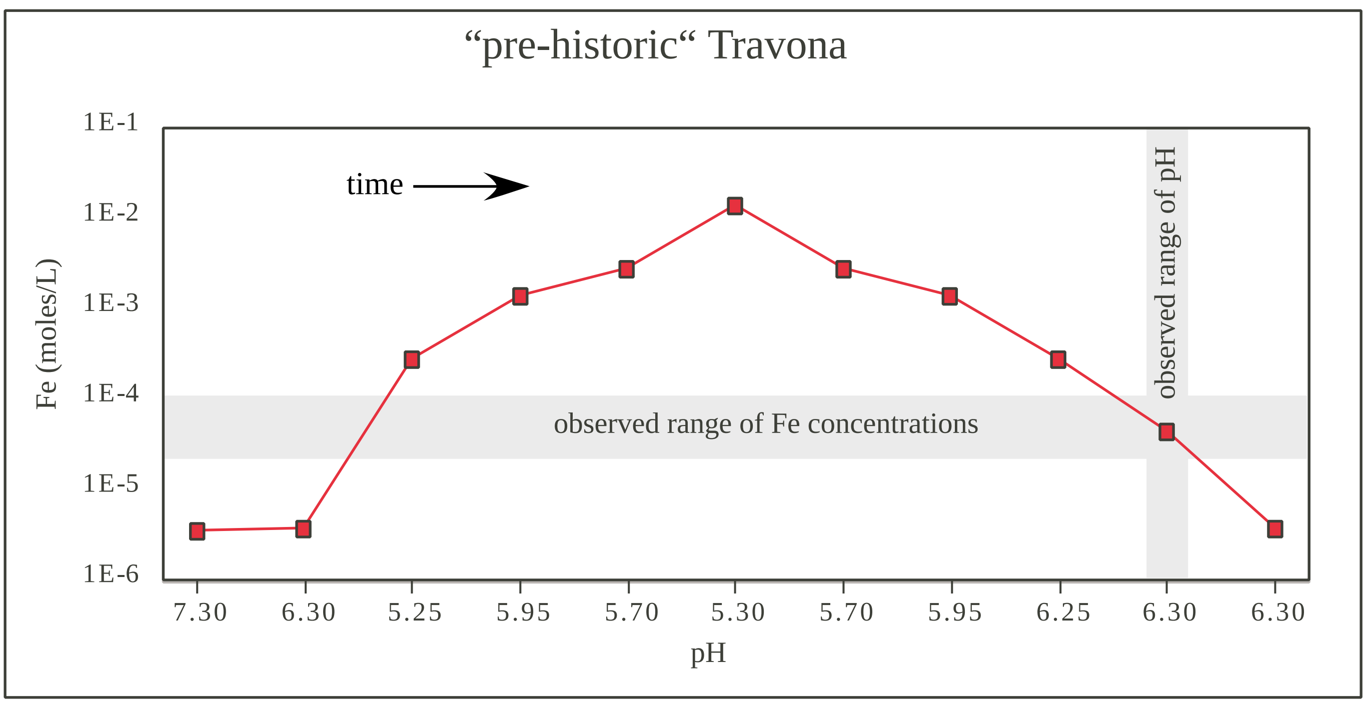


Figure 3-14b. Model results from figure 3-14a for iron as a function of pH.2

Table 3.3.4.1 Mineral phases used in the Travona simulation

Mineral Phase	Comments
Arsenolite	based on tennantite/enargite
Montmorillonite-Ca	alteration mineral
Quartz	country rock
Pyrite	
Rhodochrosite	dominant ore mineral
Chalcopyrite	reported as "occurrences"

only one point during the simulation: when oxygen has been "depleted" as the mine floods. These results further demonstrate that iron was stored as precipitates and provide additional dissolved iron as the system evolves from oxidizing to reducing conditions.

Table 3.3.4.2 compares model results for the early period of flooding to those of a sample collected from the Travona shaft on February 16, 1984. The relative percent difference (RPD) for each constituent was calculated as the ratio of the (absolute) difference to the average of each pair of values. No RPD was calculated for those constituents reported as below the instrument detection limit (IDL).

Section 3.3.4.2 Period of 1st Transition, 1986 - 1987

In the 12-month period from mid-1986 to mid-1987 the iron concentration, as well as the concentration of several other constituents, increased sharply (figure 3-15). The concentration of several dissolved constituents, especially zinc, changed from exhibiting wide fluctuations to more consistent, decreasing concentrations. Redox conditions (based on As^{3+} /As^{5+} concentrations), pH, and temperature did not change appreciably during this period. Water levels during this period rose about 40 feet from an elevation of 5,329 to 5,369 feet amsl; the uppermost mine workings of the Travona are near an elevation of 5,327 feet amsl (MBMG, unpublished records). It is likely that during this period the last large opening of the mine was flooded.

Although the presence of H_2S gas has been reported throughout the period of record, only a few measurements have been made. A single measurement during the early period of flooding (1984) indicated an H_2S concentration of 1.6 mg/L; during the long-term pumping test, concentration values ranged from < 0.1 to 0.2 mg/L; recent measurements by Gammons (2003) range from 0.1 to 0.7 mg/L. This suggests a possible control of metals solubility by H_2S when compared to the concentration trends of several dissolved constituents.

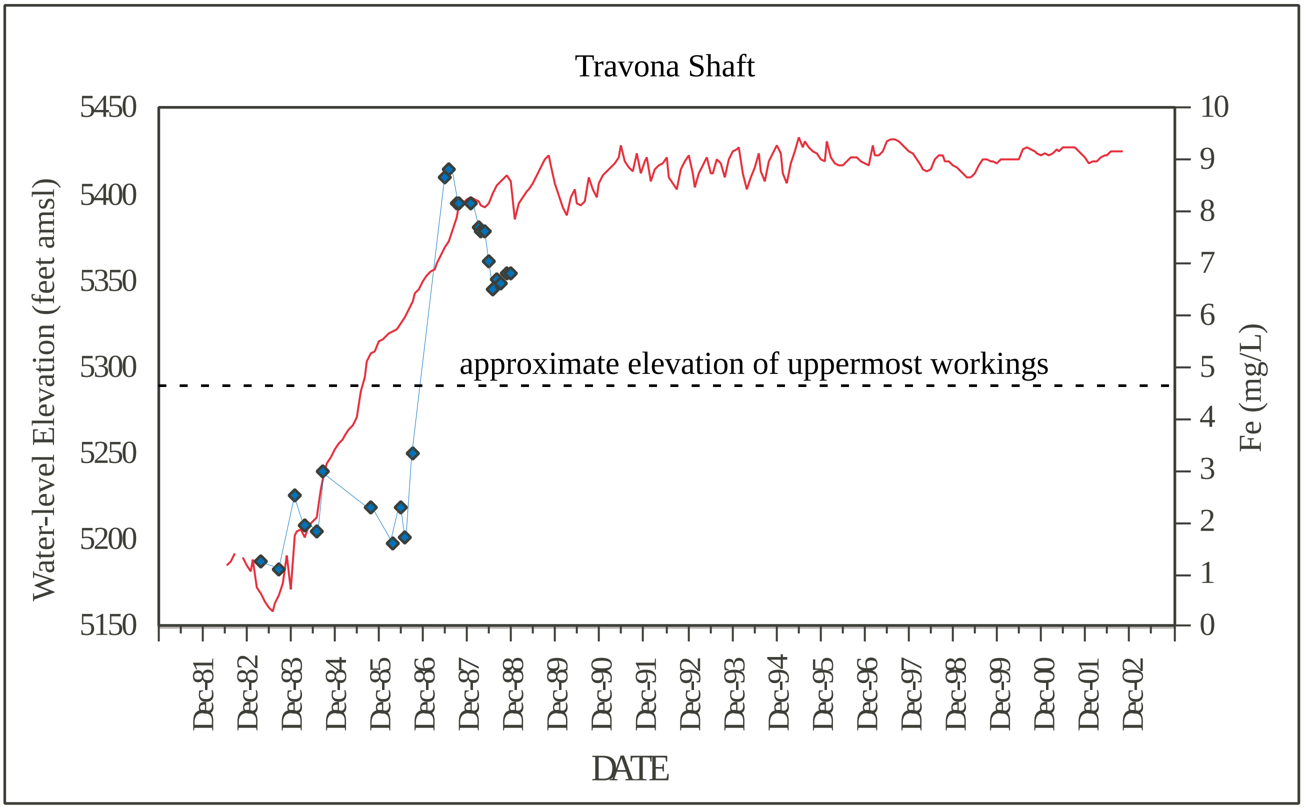


Figure 3-15. The largest increase in the concentrations of several dissolved constituents5 generally coincides with the flooding of the uppermost mine workings. 5

Table 3.3.4.2 Comparison of model results with sample collected in the early period of flooding of the Travona shaft, 1984

	MODEL		SAMPLE		DIFFERENCE		RPD
Analyte	molality	mg/L	molality	mg/L	molality	mg/L	
Al	8.718E-007	0.02	1.484e-006	0.04	1.35E-006	0.04	87
As	1.660E-006	0.12	1.042E-006	0.08	-6.18E-007	-0.05	46
C	7.157E-003		7.52E-003		3.63E-004	4.36	5
HCO_3^-	4.24E-003		4.67E-003		4.30E-004	0.00	10
CO_2	2.91E-003		2.69E-003		-2.17E-004	-0.00	8
Ca	5.145E-003	206.21	3.521E-003	141.12	-1.62E-003	-65.09	37
Cl	1.189E-003	42.15	1.005E-003	35.63	-1.84E-004	-6.52	17
Cu	8.478E-026	0.00	<IDL		-8.48E-026	-0.00	
F	3.478E-005	0.66	3.688E-005	0.70	2.10E-006	0.04	6
Fe	5.148E-005	2.88	4.499E-005	2.51	-6.49E-006	-0.36	13
K	1.434E-004	5.61	1.152E-004	4.50	-2.82E-005	-1.10	22
Mg	2.421E-003	58.85	1.709E-003	41.55	-7.12E-004	-17.31	34
Mn	5.084E-005	2.79	4.810E-005	2.64	-2.74E-006	-0.15	6
Na	1.372E-003	31.53	3.009E-003	69.15	1.64E-003	37.62	75
SO_4	5.459E-003	175.02	4.074E-003	130.61	-1.39E-003	-44.40	29
Zn	1.547E-006	0.10	1.501E-006	0.10	-4.60E-008	-0.00	3
S^{-2}	4.154E-006	0.14	6.00E-006	0.20	1.85E-006	0.06	36

The concentration of iron in the Travona shaft displays an inverse relationship with H_2S (increasing iron = decreasing H_2S) concentrations as suggested by:

$$Fe^{2+} + H_2S_{(aq)} = FeS_{(am)} + 2H^+ \qquad \log K_{eq} = -2.69 \text{ (Langmuir, 1997)}$$

Figure 3-16 presents the solubility of Fe^{2+} with respect to H_2S over the range of total iron and H_2S observed in the Travona shaft. Although the inverse relationship holds, the values for H_2S and Fe^{2+} predicted by this equation are much lower than those observed.

The concentration of zinc in the Travona shaft displays a direct proportional relationship with the concentration of H_2S (decreasing zinc = decreasing H_2S), but solubility is a function of both Zn^{2+} and zinc-bisulfide as described by:

$$ZnS_{(s)} + H_2S^O = Zn(HS)_2^O \qquad \log K_{eq} = -5.3$$

and

$$ZnS_{(s)} + H_2S^O = Zn^{2+} + 2HS^- \qquad \log K_{eq} = -18.47 \text{ (Dsklakis and Helz, 1993)}$$

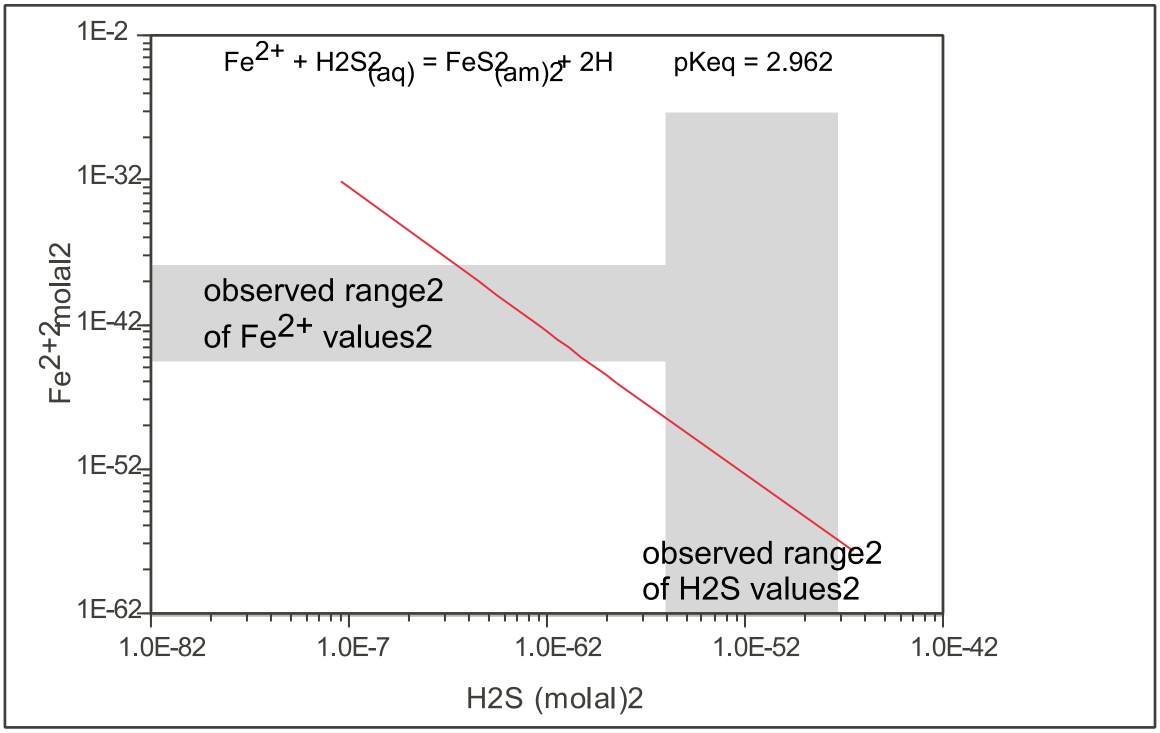


Figure3-16. Solubility curve for Fe^{2+} at pH 6.5 based on Langmuir (1997).

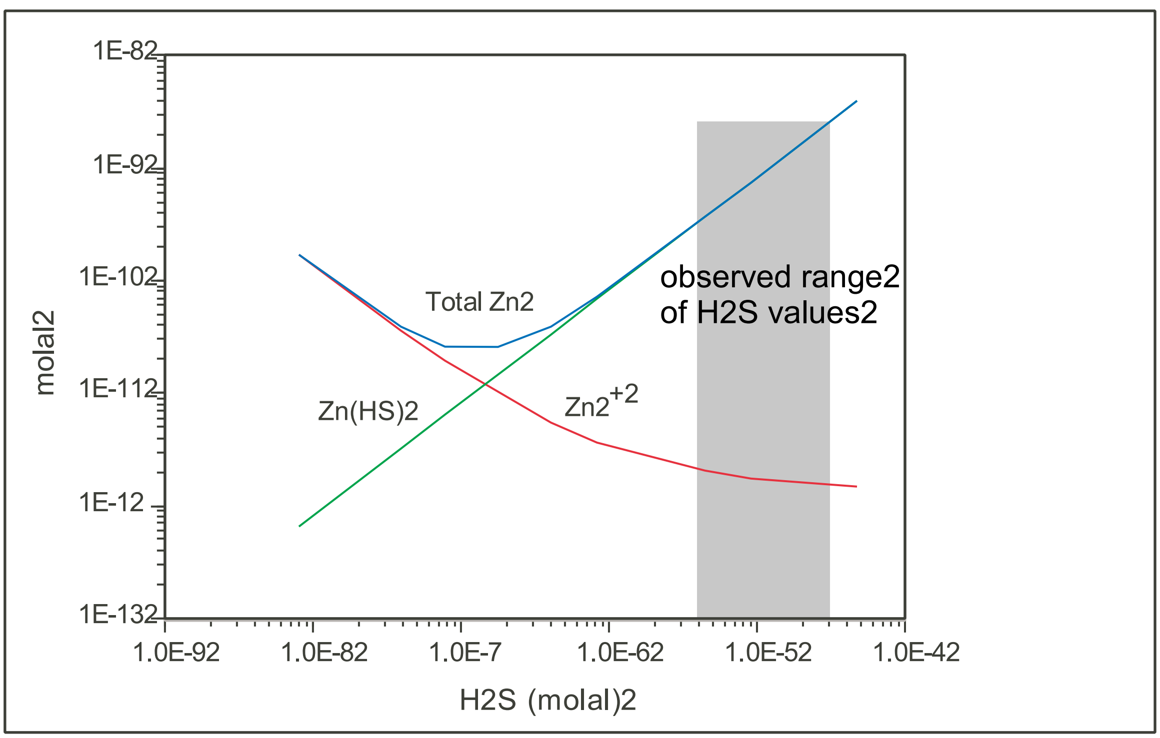


Figure 3-17. Solubility curve for sphalerite at pH 6.5 (after Dskalakis and Helz, 1993).2

Figure 3-17 presents solubility of Zn^{2+} with respect to H_2S over the range of total zinc and H_2S observed in the Travona shaft. Although the proportional relationship holds within the observed range of observations, the values for H_2S and total zinc predicted by this equation are much lower than those observed.

Table 3.3.4.3 compares model results for the period during which concentrations showed the greatest change, about mid-1987. These model data were generated by saving the solution from the baseline step, continuing equilibration with the listed mineral phases, and changing H_2S concentrations.

Table 3.3.4.3 Comparison of model results to a sample collected in mid-1987 from the Travona Shaft

	MODEL		**SAMPLE**		**DIFFERENCE**		**RPD**
Analyte	molality	mg/L	molality	mg/L	molality	mg/L	
Al	8.299E-007	0.02	<IDL	0.00	-8.30E-007	-0.02	
As	2.860E-006	0.21	2.338E-006	0.18	-5.22E-007	-0.04	20
C	7.246E-003		7.52E-003		2.74E-004	3.29	4
HCO_3^-	4.08E-003		4.84E-003		7.59E-004	0.00	
CO_2	2.91E-003		2.93E-003		2.70E-005	0.00	1
Ca	5.145E-003	206.21	4.621E-003	185.21	-5.24E-004	-21.00	11
Cl	1.189E-003	42.15	9.798E-004	34.73	-2.09E-004	-7.42	19
Cu	8.429E-026	0.00	<IDL		-8.43E-026	-0.00	
F	3.478E-005	0.66	2.108E-005	0.40	-1.37E-005	-0.26	49
Fe	1.127E-004	6.29	1.581E-004	8.83	4.54E-005	2.54	34
K	1.434E-004	5.61	1.280E-004	5.00	-1.54E-005	-0.60	11
Mg	2.421E-003	58.85	2.322E-003	56.45	-9.90E-005	-2.41	4
Mn	3.926E-004	21.57	5.248E-004	28.83	1.32E-004	7.26	29
Na	1.372E-003	31.53	2.865E-003	65.84	1.49E-003	34.31	70
SO_4	5.469E-003	175.34	4.075E-003	130.64	-1.39E-003	-44.69	29
Zn	1.547E-006	0.10	1.685E-006	0.11	1.38E-007	0.01	9
S^{-2}	2.207E-006	0.08	no data	-	-	-	-

The model gives better results than the calculations based on individual reactions for iron. The change in H_2S concentration required to change the iron concentration was not enough to change the zinc concentration; this disagrees with the results predicted by Dsklakis and Helz (1993), but generally agrees with observed results.

Section 3.3.4.3 Period of 2nd Transition, 1987 to present

The concentrations of nearly all of the dissolved constituents decreased steadily after the flooding of the uppermost workings of the Travona. As^{3+}/As^{5+} data indicate a slight decrease in redox conditions; H_2S measurements by Gammons and others (2003) indicate a slight increase in concentration compared to early flooding and a slight decrease compared to data collected during the pumping test of 1989.

Pumping from the mine shaft was initiated in 1989 to control water levels. For the first several years, the shaft was pumped at rates between 200 and 500 gpm for several months and then allowed to rise. In 1996, pumping was made continuous and the pumping rate was reduced; in 1997, the pumping station (and sampling point) was moved from the shaft to a well completed in the upper workings.

Additional modeling of the latter period of flooding consisted of adjusting (increasing) the concentration of H_2S from values used for the 1986-1987 period, but maintaining a value less than that used to simulate the early period of flooding (1984-1986). Model results generally agreed well with those observed.

Section 3.3.4.4 Summary of Travona Mine

With respect to several major cations and anions (e.g., Ca, Mg, K, Si, N, and Al), ground water flowing into the Travona Mine shows variation greater than that of the water within the shaft. Conversely, other constituents such as arsenic, iron and zinc are controlled by processes within the workings of the mine.

Controls on the water chemistry of the Travona Mine have varied with the progression of flooding. Although data do not exist, there is good evidence of at least minor acid generation in the earliest flooding of the mine in the 1950's. The Travona and the West Camp in general, are up-gradient of and isolated from the other mines in the district. As a result, the water chemistry is influenced only by ground water flowing into the mine and local mineralogy rather than by waters flowing in from other mines. As the mine flooded, the interaction of minerals and oxygen was reduced and redox conditions favored the production of H_2S until this, more than any other influence, controlled the chemistry of iron, zinc and manganese.

SECTION 4.0 OUTER CAMP SYSTEM

The Outer Camp System consists of the Orphan Boy Mine, Marget Ann Mine, well S-4 and the Montana Tech well (figure 4-1). It is believed that water levels in the Outer Camp System are at or near pre-mining conditions, as these mines had not operated for many years prior to ARCO's suspension of underground mining. It is also believed the few interconnections that existed between these mines and other Butte Hill mines had been sealed off decades earlier by the placement of bulkheads.

Outer Camp water levels continued to decline in 2002, following the trend first seen in 1999.

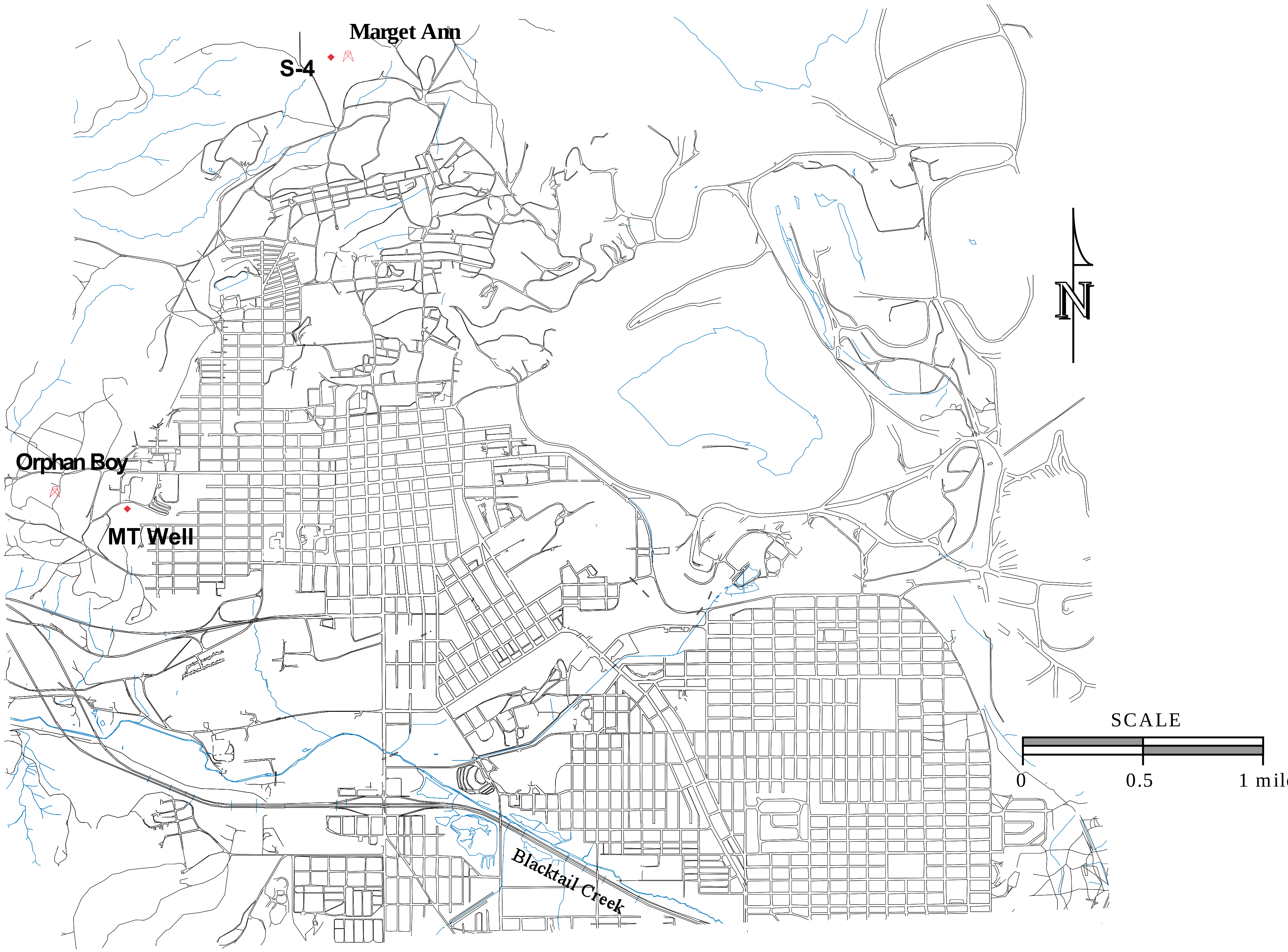


Figure 4-1. Outer Camp Monitoring Sites Location Map.

Table 4.0.1 contains yearly water-level change data, while figure 4-2 shows these changes graphically.

Table 4.0.1 Annual Water-Level Changes for the Outer Camp Sites, in feet

Year	Orphan Boy	Marget Ann	Well S-4	MT Tech Well
1987	2.40			
1988	-1.10	-3.56	-3.56	
1989		-1.34	-4.23	
1990				
1991				
1992	1.41			
1993	5.49			0.36
1994	-0.72	4.66		2.51
1995	5.44	12.41		6.48
1996	-0.96	10.44	18.41	-1.47
Total 10-Year Change*	***11.96***	***22.61***	***10.62***	***7.88***
1997	7.56	14.50	16.42	7.76
1998	-2.79	0.59	2.17	-2.72
1999	-1.94	-2.87	-2.32	-1.57
2000	NA	-0.95	-1.31	-4.24
2001	NA		-1.59	-1.79
2002	NA	-2.65	-2.90	-3.64
Total Change*	***14.79***	***25.98***	***18.32***	***1.68***

(*) Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

Surface subsidence around the Orphan Boy Mine shaft has prevented monitoring of this site since June 1999. However, based upon previous comparisons between this site and the Montana Tech well, water levels probably continued to decline throughout 2002.

Figure 4-3 shows water levels for the Orphan Boy Mine and the Montana Tech well, along with monthly precipitation amounts. Water levels in the Montana Tech well showed the same response to precipitation events as was seen in 2001 and prior years, rising in the spring and declining throughout the winter.

Water levels in the Marget Ann Mine and well S-4 decreased between 2.65 feet and 2.90 feet during 2002. Figure 4-4 shows water-level hydrographs for these two sites with monthly precipitation totals shown. Water levels from 1994 through 1998 showed a consistent increase throughout this time period regardless of precipitation amounts. Since then, water levels have fallen, but still appear to have little influence from precipitation. Water levels in the Marget Ann Mine and well S-4 dropped throughout 2002 regardless of precipitation trends.

Section 4.0.1 Outer Camp System Water Quality

Water quality in the Marget Ann shaft and well S-4 nearby have shown little change in recent years. Data collected in 2002 indicated a continued trend on all accounts. Overall, the

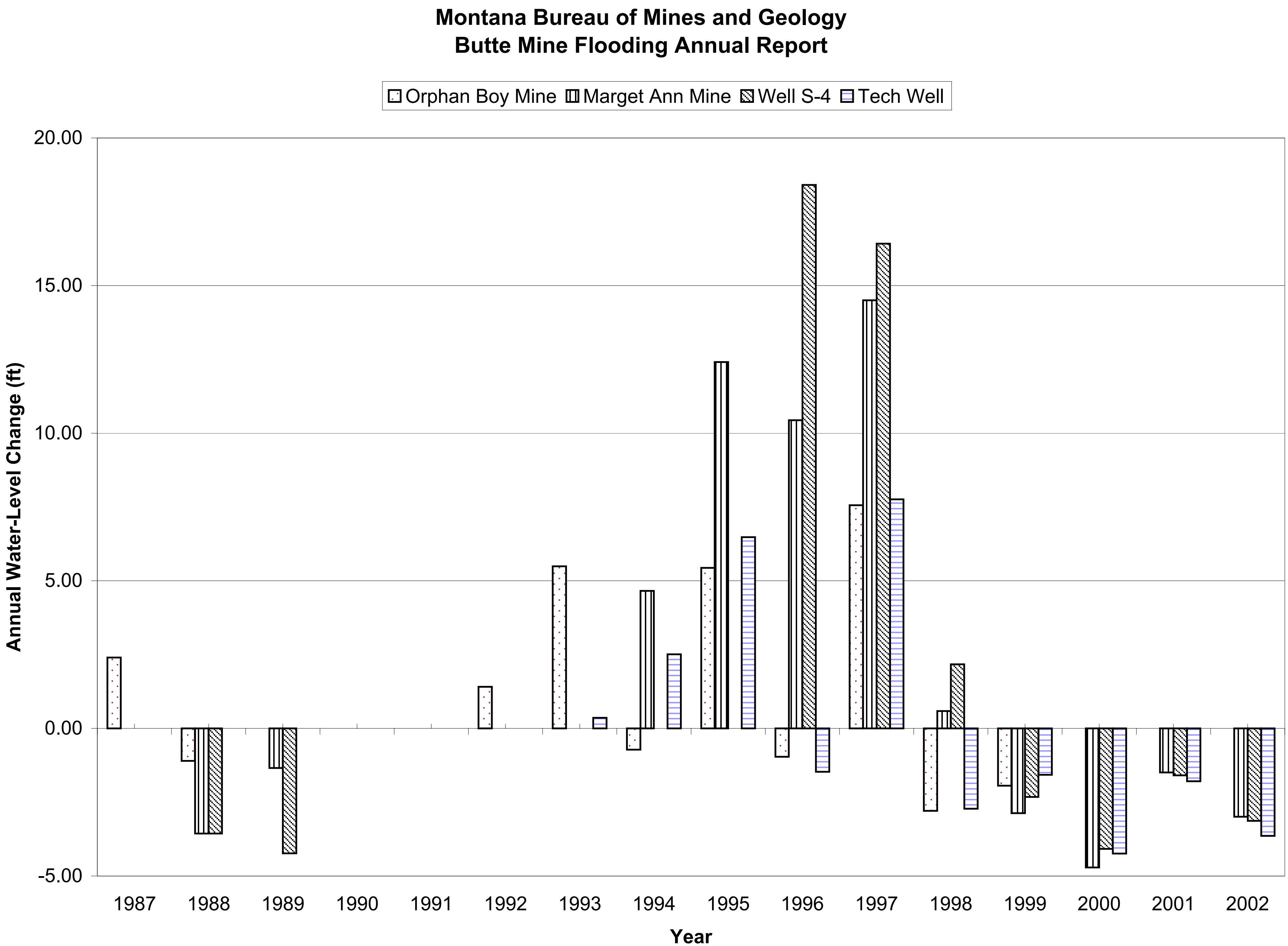


Figure 4-2. Outer Camp sites annual water-level change.

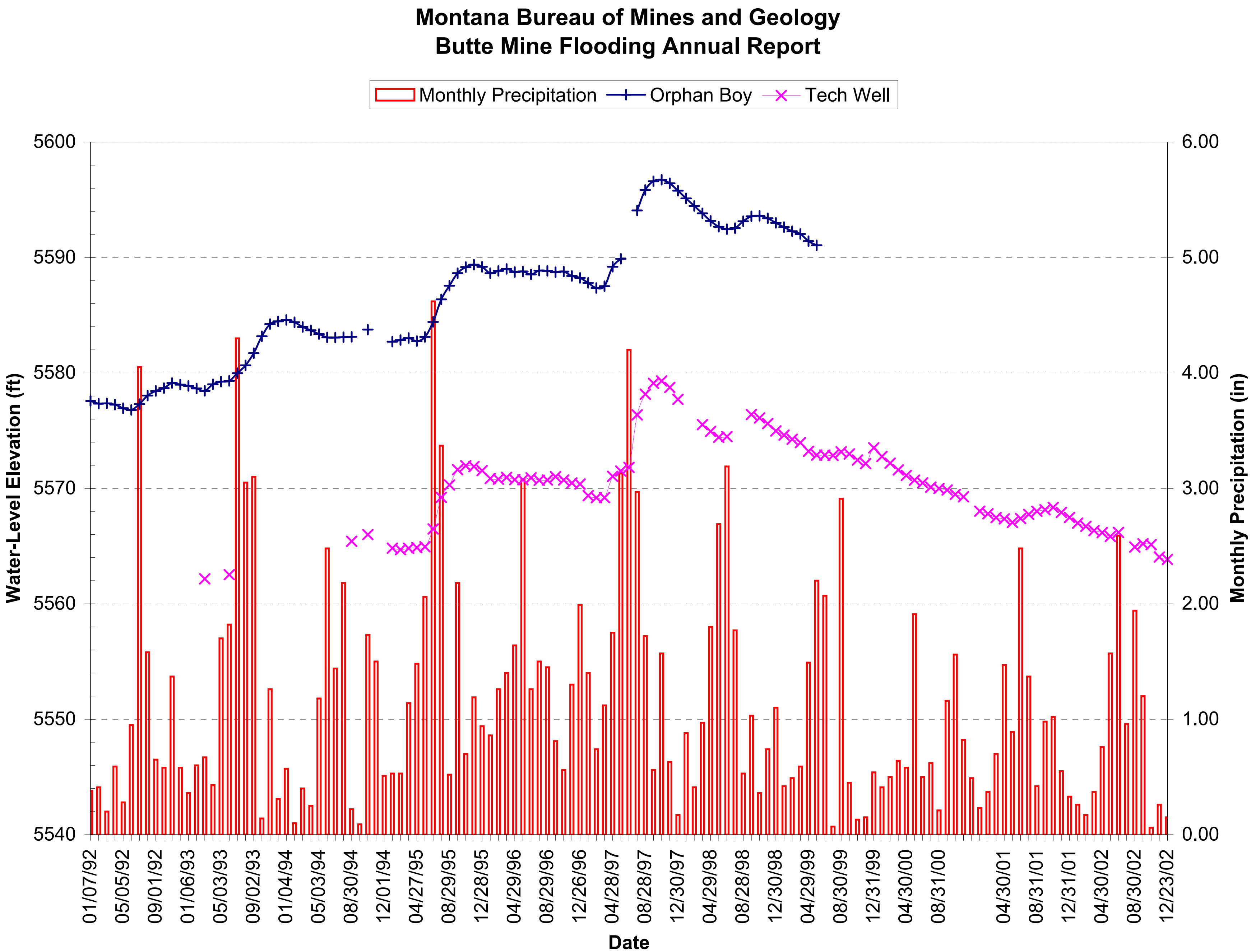


Figure 4-3. Water-level hydrograph of the Orphan Boy Mine and Montana Tech wells.

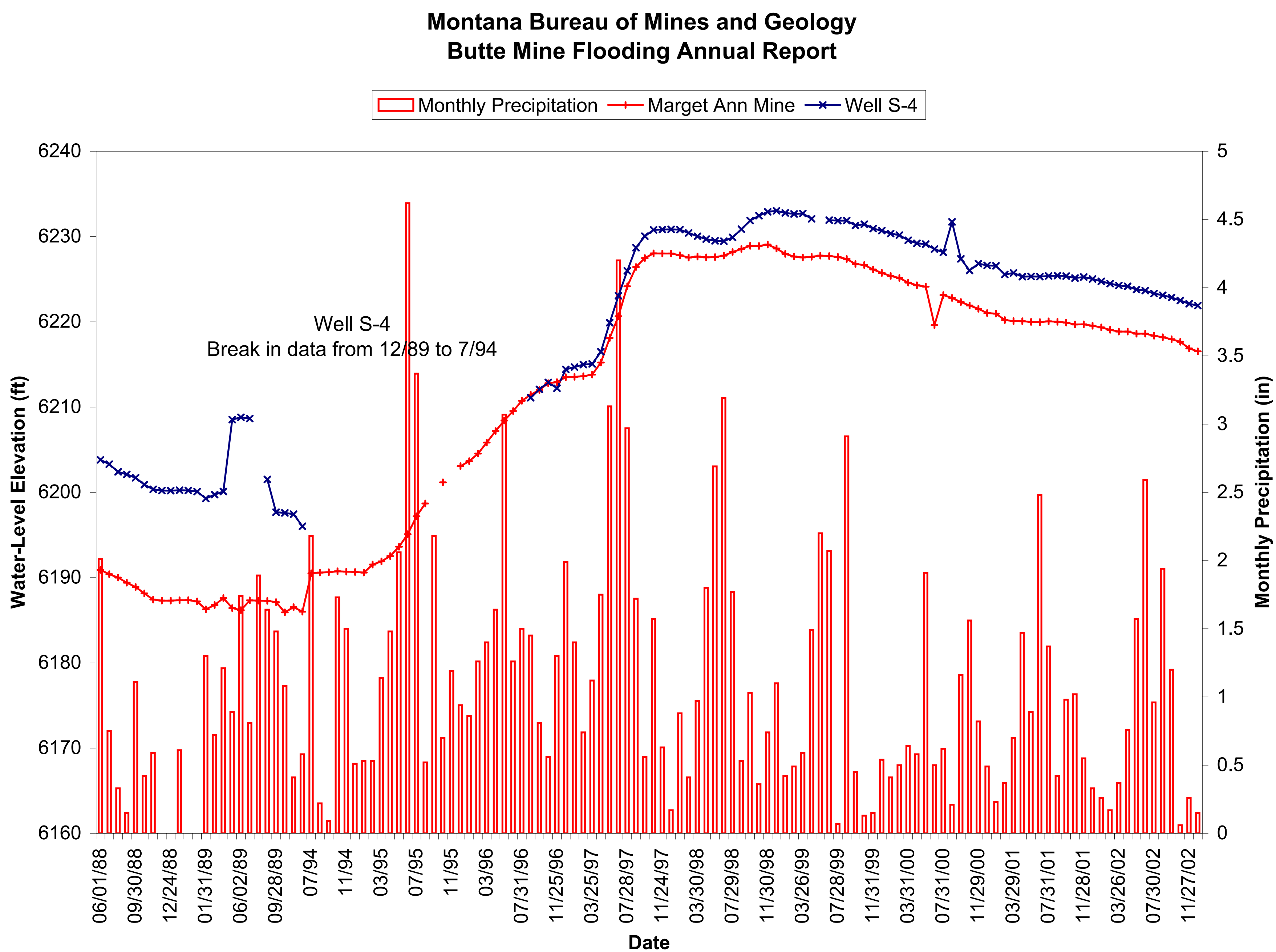


Figure 4-4. Water-level hydrograph for Marget Ann Mine and well S-4.

concentrations of dissolved metals are low and most are well below MCLs and SMCLs. The concentration of dissolved constituents is fairly consistent between the shaft and the well; most concentrations are within a few percent of each other. The concentration of sulfate has ranged from 200 to 350 mg/L for both sites and field redox measurements are consistently low. Selected chemistry for both sites, including sulfate, is presented in figures 4-5a and 4-5b.

SECTION 5.0 MISCELLANEOUS WELLS

The locations of the miscellaneous monitoring wells are shown on figure 5-1. These sites consist of 11 shallow alluvial monitoring wells (MF) and two bedrock monitoring wells. Two of the alluvial wells have been damaged and are no longer being monitored. A third alluvial well (MF-4) was plugged and abandoned in 2001, to allow reclamation activities associated with Butte Priority Soils work. While the Hebgen Park and Parrott Park wells are both part of the monitoring program specified in the 2002 CD, the shallow alluvial wells (MF) are not.

Water levels rose in three of the alluvial wells and fell in the remaining alluvial wells during 2002. Annual water-level changes are listed in Table 5.0.1. Total water-level changes since 1983 are less than two feet (up or down) in these wells.

Figures 5-2, 5-3, and 5-4 are water-level hydrographs for alluvial wells MF-1, MF-05, and MF-10, showing monthly water-level variations along with monthly precipitation totals. Water levels respond to precipitation events very quickly in all of these wells. Water-level variations are greater in wells MF-05 and MF-10 than those seen in well MF-01. Water levels gradually increased in those two wells from 1993 through 1998 before declining during most of 1999 and 2000. Water levels have stabilized somewhat the past two years. Water-level response to precipitation was much more dramatic in 2001 and 2002 than in the two previous years. While precipitation totals for 2001 and 2002 were still below the long-term average, they were much greater than those of 2000, which might account for the increased water-level response seen on the hydrographs for these wells.

Water levels were not measured in the Hebgen Park well from February through August 2002 due to access problems. Therefore, it is hard to draw too many conclusions about the response between water levels and precipitation, but it does appear that there was a slight increase in water levels during the late summer (figure 5-5). The rise coincides with both summer precipitation and lawn watering of the park. Since the water-level rise extends into the fall and early winter, it is probable that most of the increase in water level is due to lawn watering and not the result of precipitation.

The water-level hydrograph for the Parrott Park well is shown on figure 5-6, along with monthly precipitation totals. Water levels declined during most of the year before leveling off and rising during December of 2002. As a result, this well had a water-level decline of over three feet for 2002. This year's decline follows an almost 7-foot rise during 2000 and 2001. Once again, it appears that

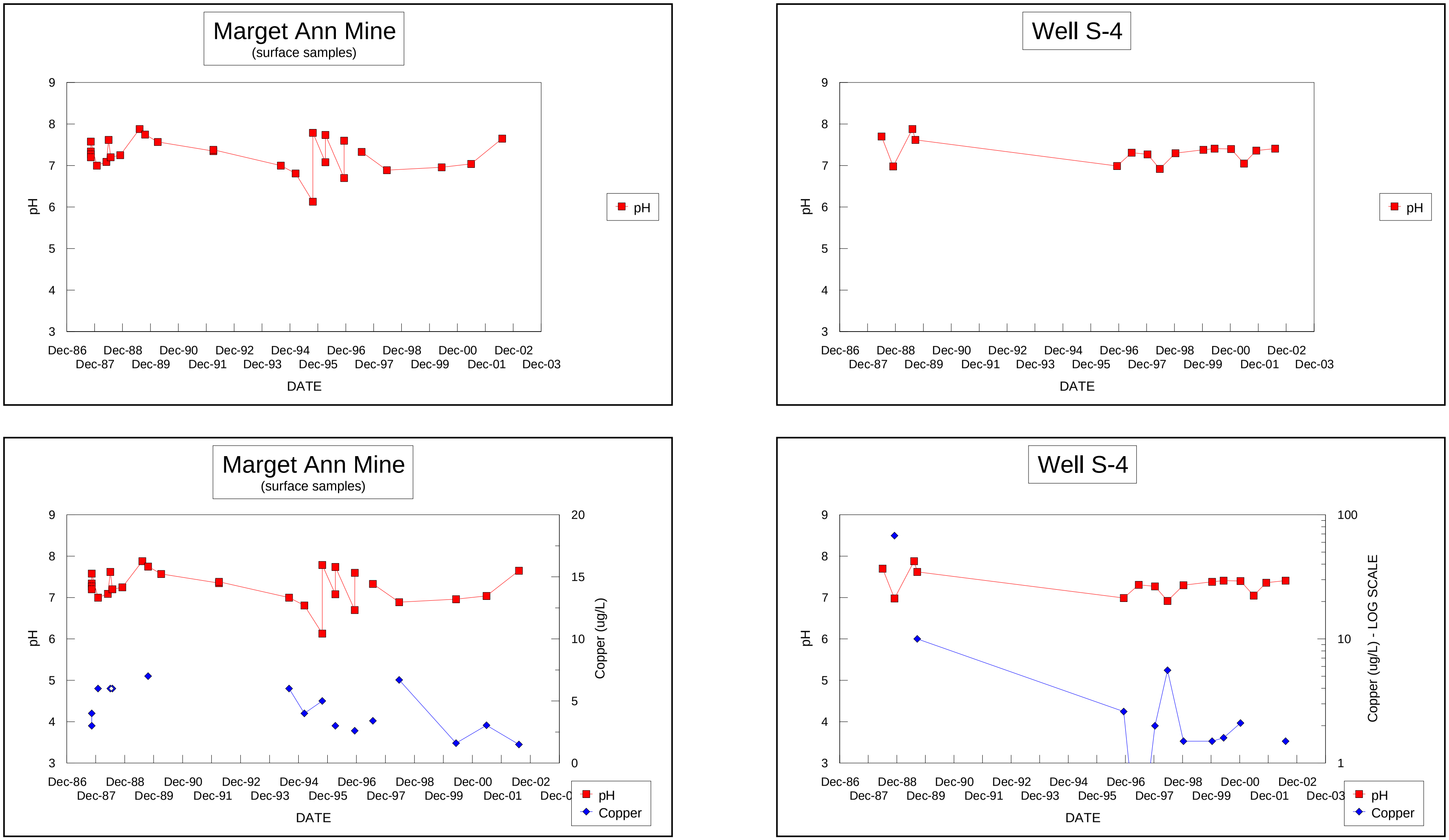


Figure 4-5a. Selected chemistry for the Marget Ann mine and Well S-4 in north Walkerville.

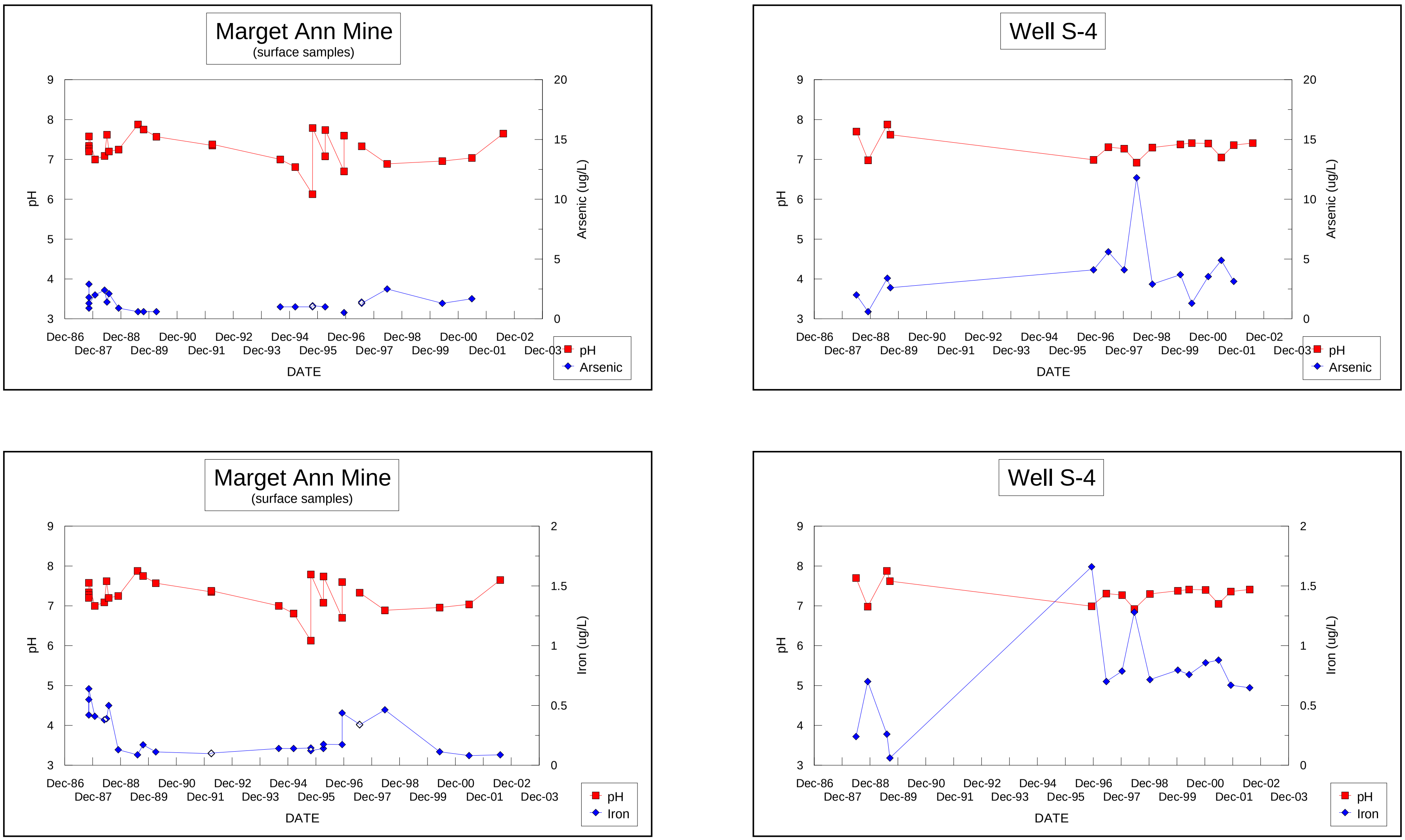


Figure 4-5b. Selected chemistry for the Marget Ann mine and Well S-4 in north Walkerville.

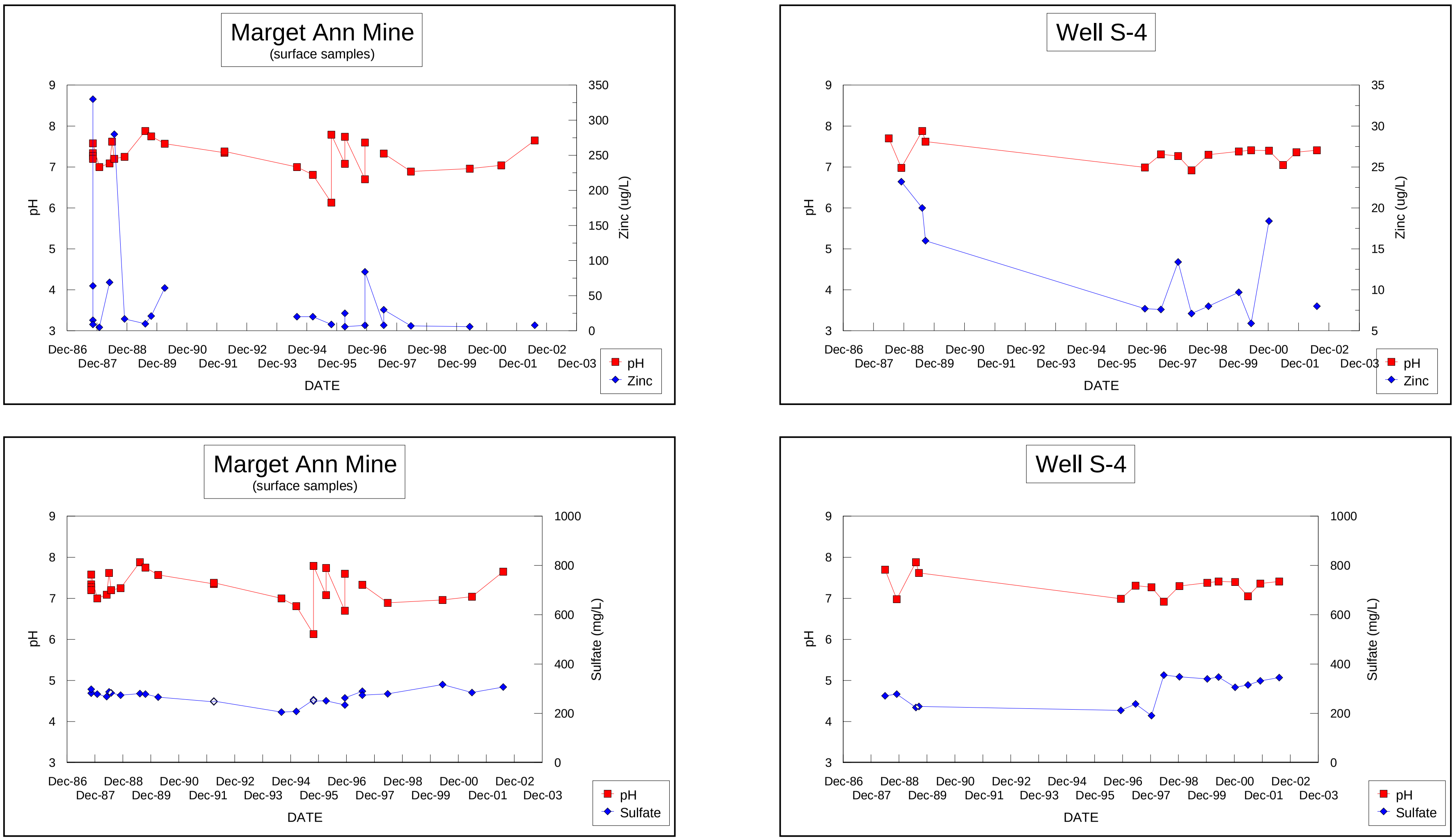


Figure 4-5c. Selected chemistry for the Marget Ann mine and Well S-4 in north Walkerville.

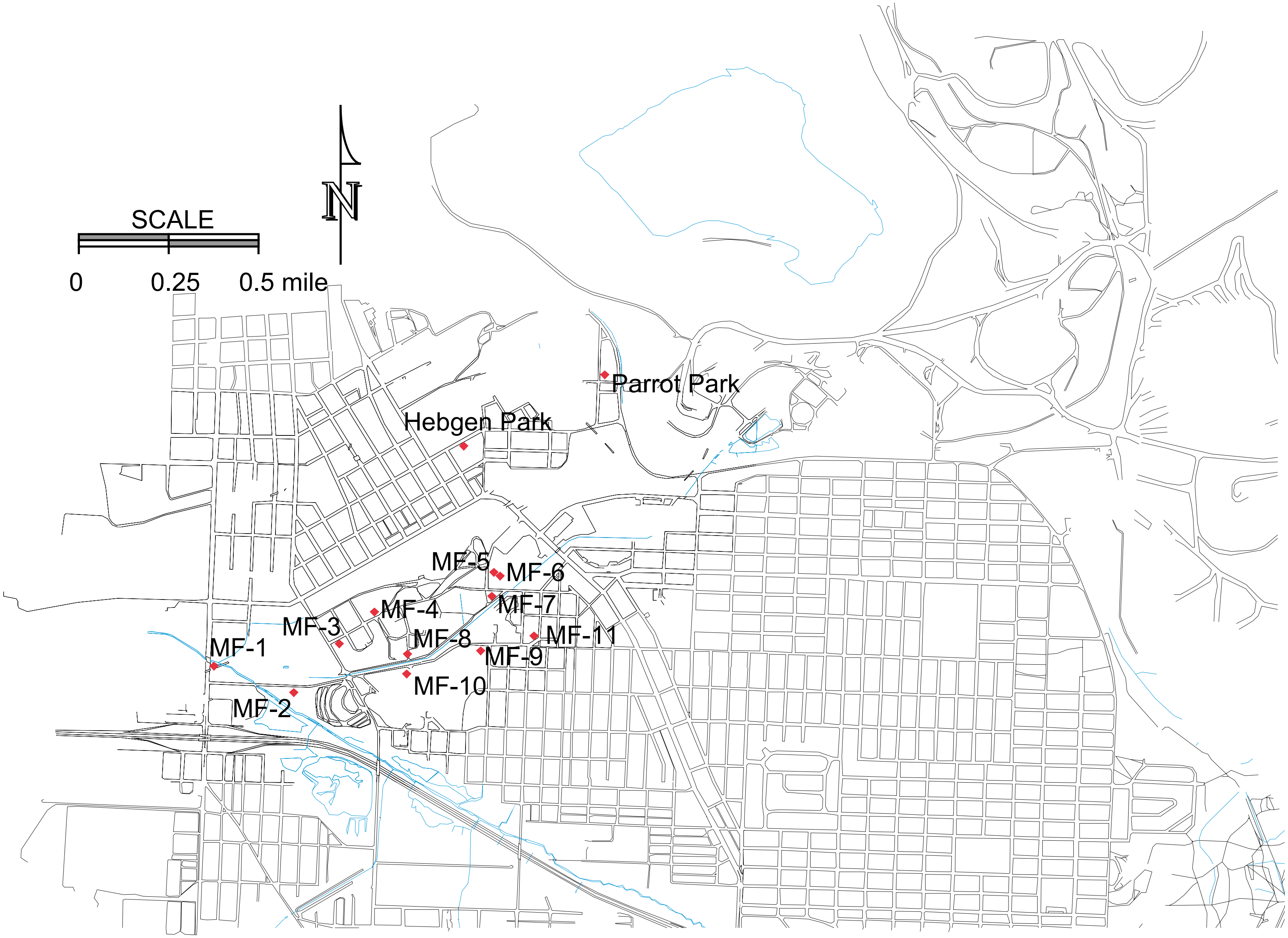


Figure 5-1. Miscellaneous Monitoring Wells Location Map.

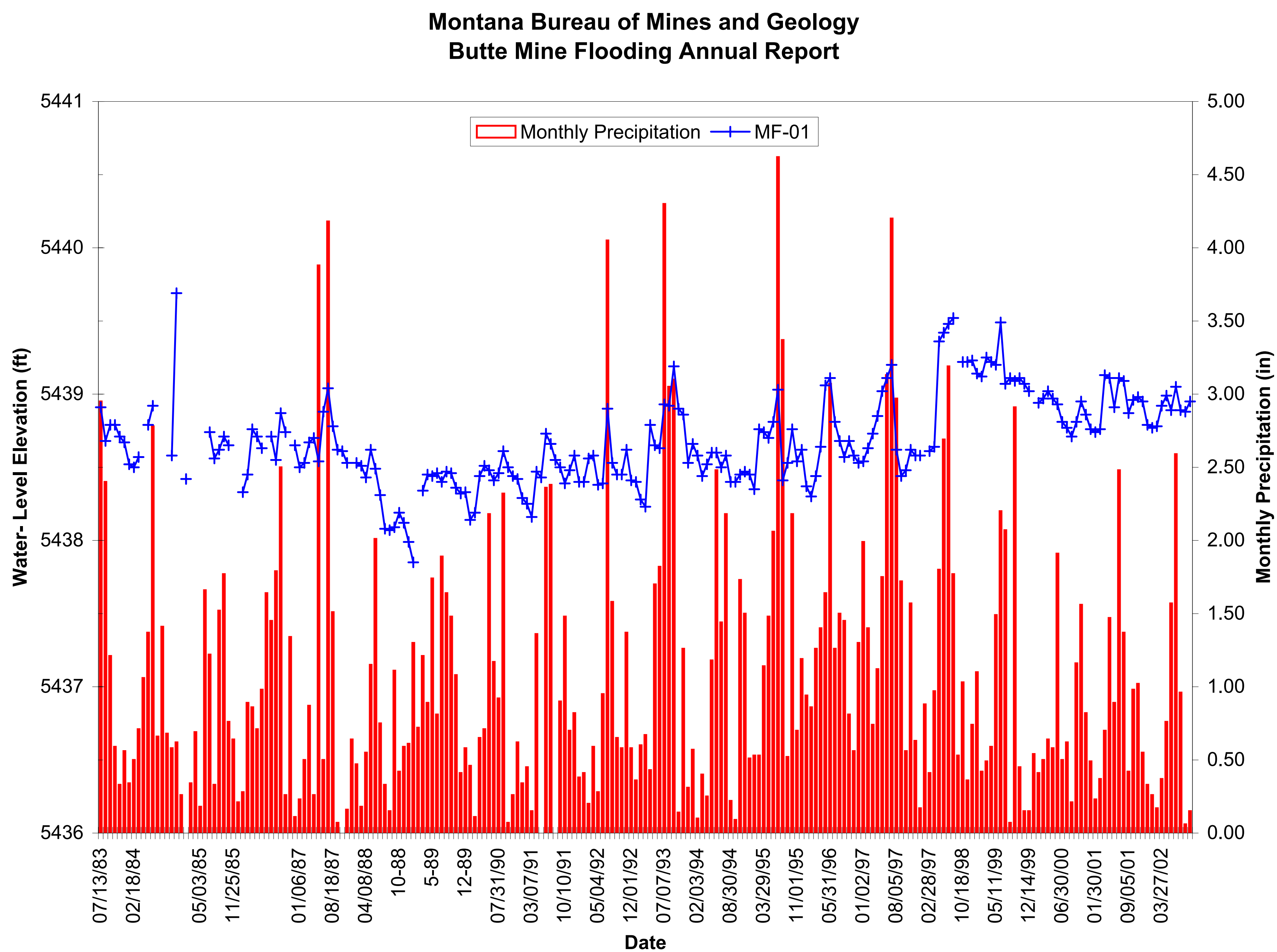


Figure 5-2. Water-level hydrograph for MF-01 well.

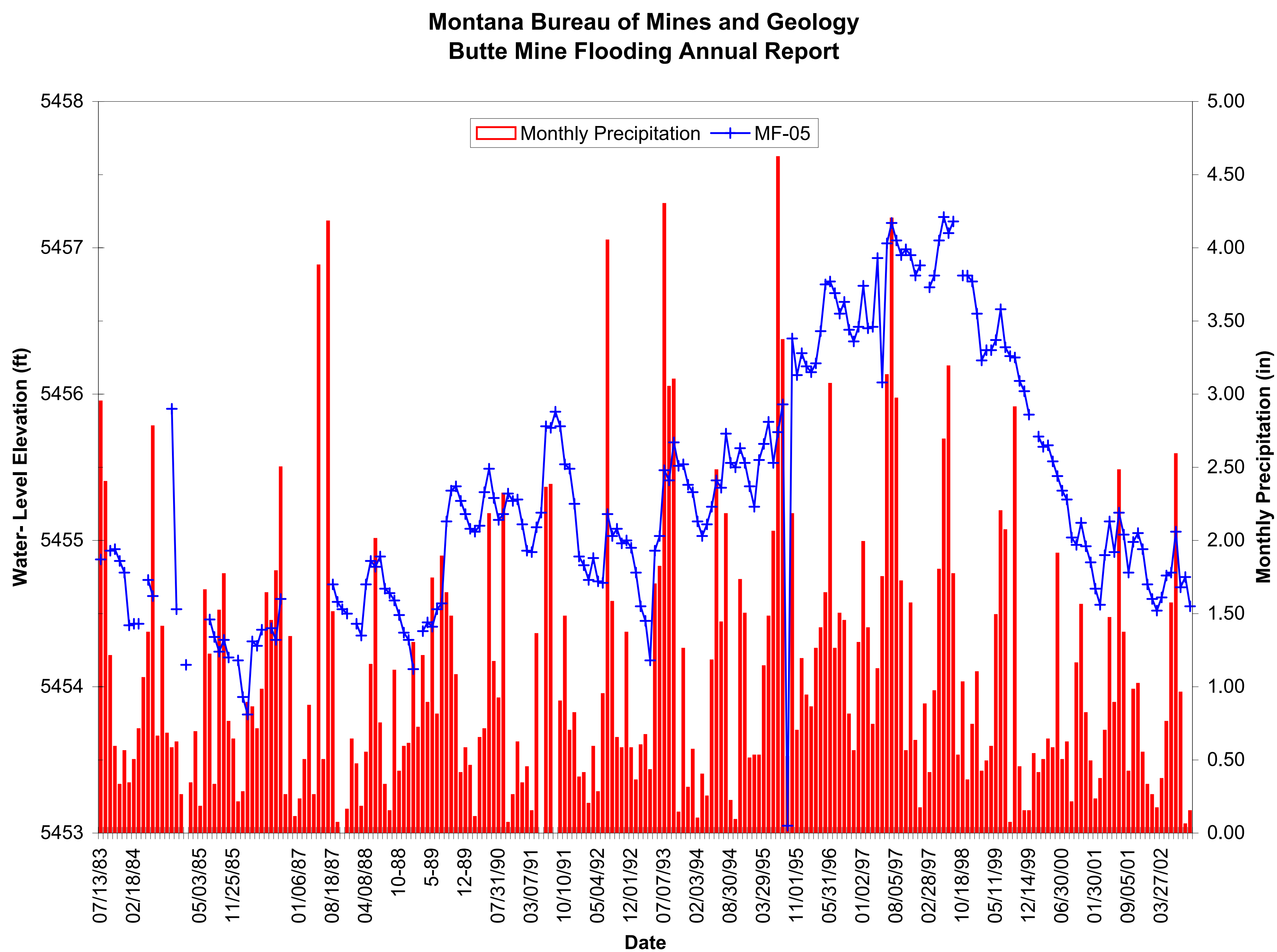


Figure 5-3. Water-level hydrograph for MF-05 well.

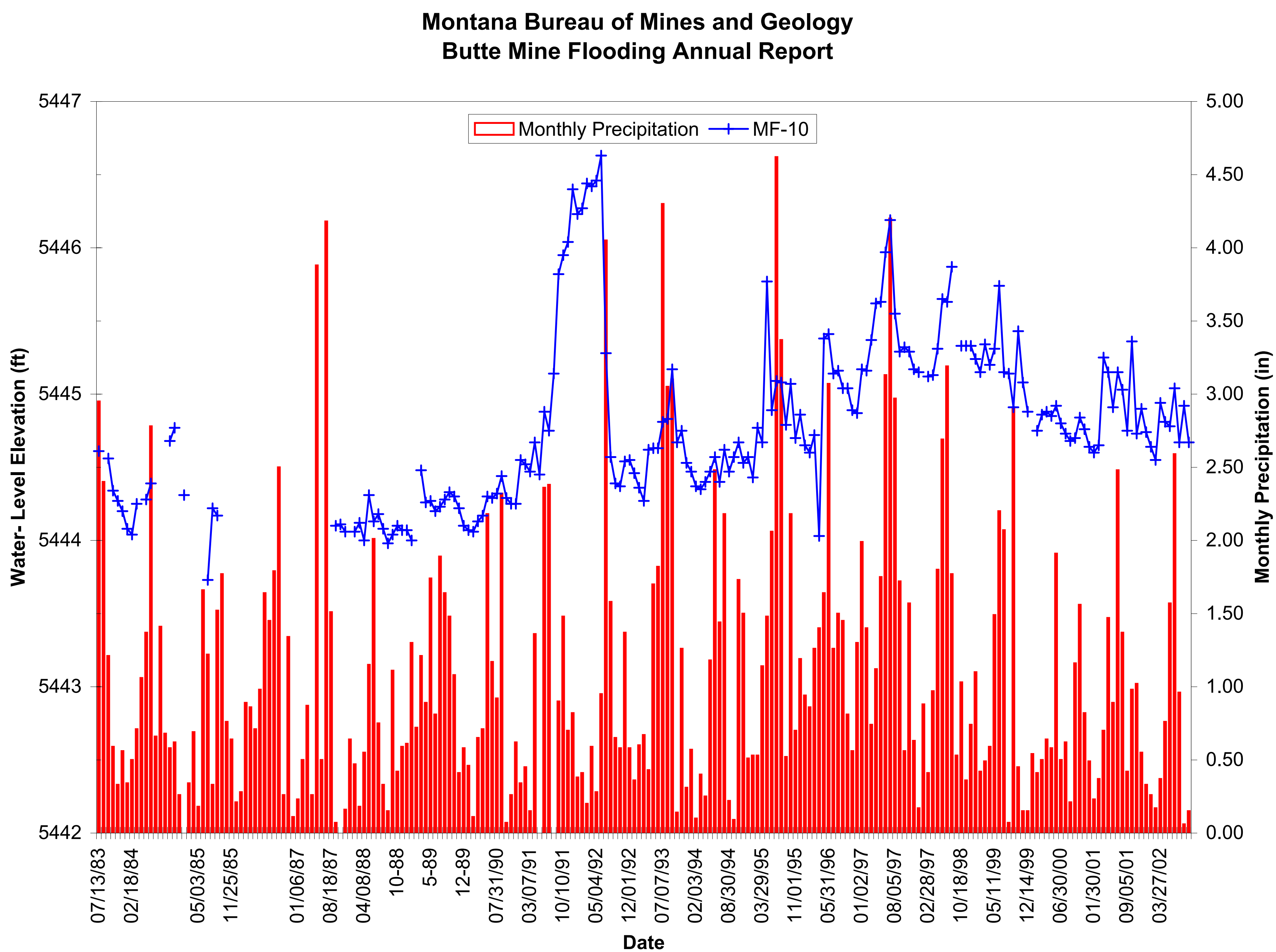


Figure 5-4. Water-level hydrograph for MF-10 well.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

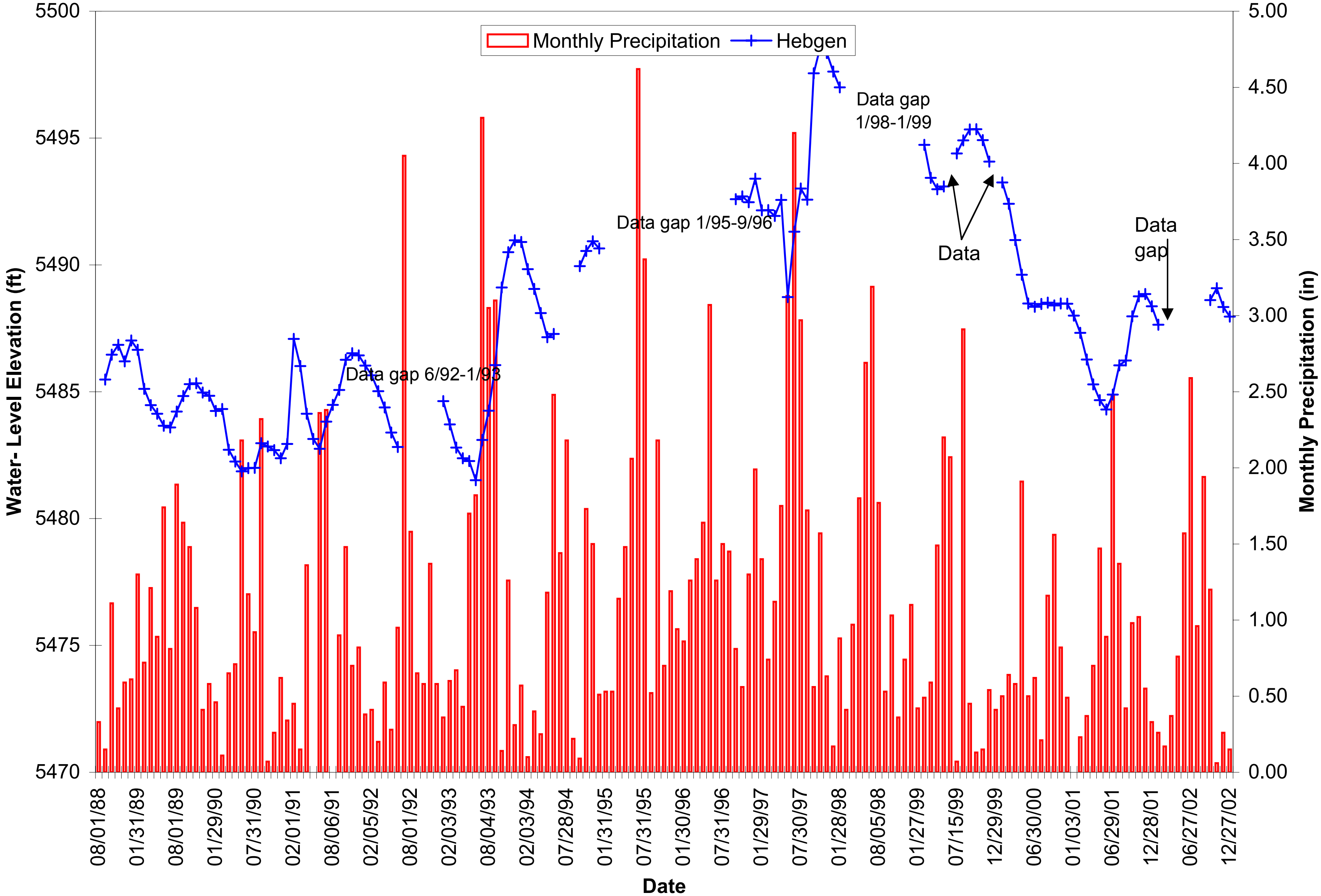


Figure 5-5. Water-level hydrograph for the Hebgen Park Well.

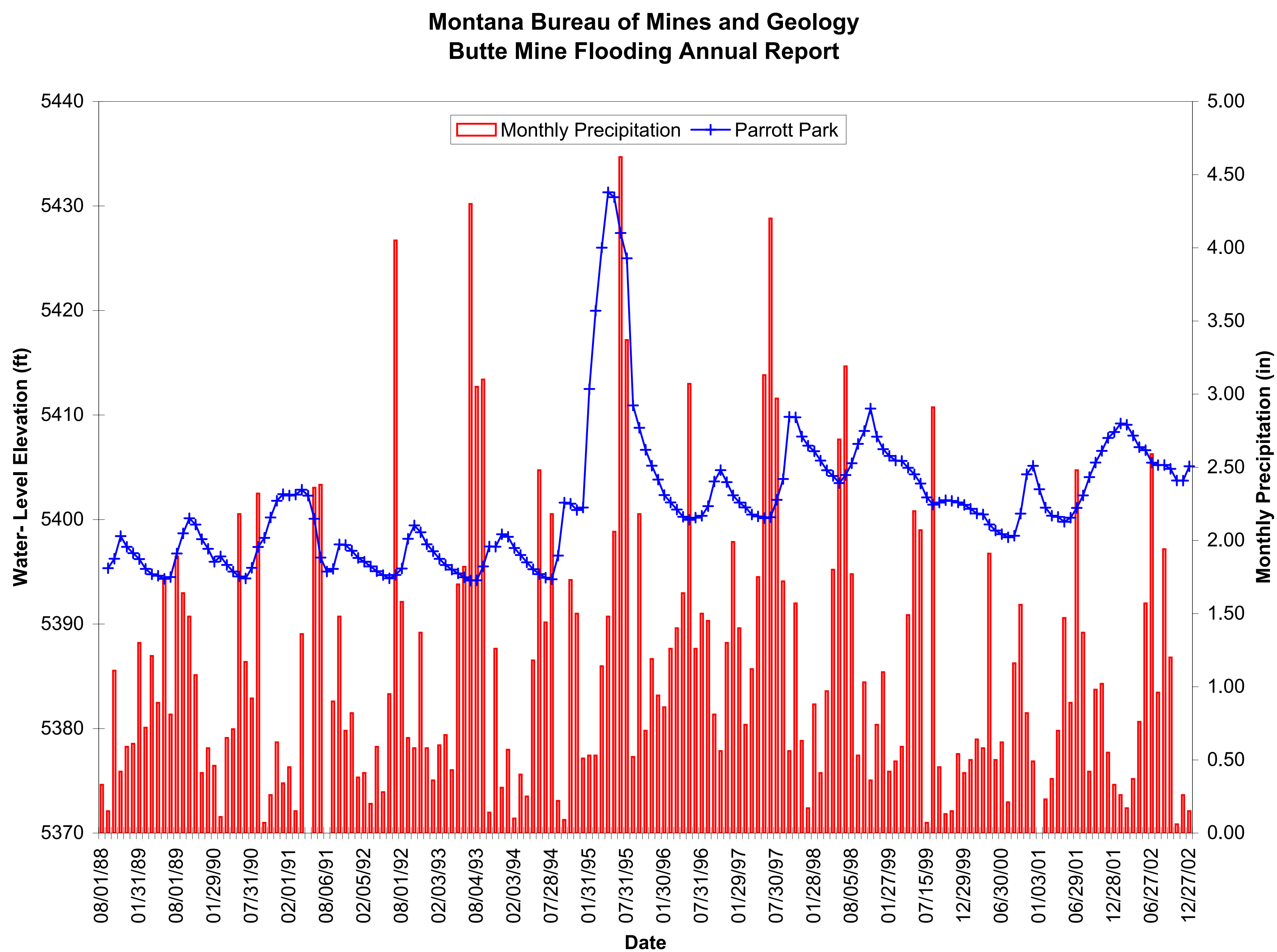


Figure 5-6. Water-level hydrograph for Parrott Park well.

Table 5.0.1 Annual Water-Level Change for Miscellaneous Wells, in feet

Year	MF-1	MF-2	MF-3	MF-4	MF-5	MF-6	MF-7	MF-8	MF-9	MF-10	MF-11	Hebgen (1)	Parrott
1983	-0.24	-0.13	-0.64	-0.20	-0.09	-0.09	-0.93	0.53	-0.65	-0.41	-0.59		
1984	1.02	-0.09	-0.03	0.89	-0.25	-0.14	0.37	0.09	-0.28	0.57	-0.23		
1985	-1.00	-0.02	0.19	-0.21	-0.33	0.59	-1.17	-0.01	-0.10	-0.60	-0.29		
1986	0.00	0.10	0.22	0.29	0.40	0.08	1.01	0.13	-0.10	0.00	-0.35		
1987	-0.12	-0.05	-0.37	-0.88	-0.10	-0.99	-0.01	-0.03	-0.41	-0.11	0.45		
1988	-0.54	-0.05	0.08	0.38	-0.18	-0.13	-0.01	-0.05	0.17	0.01	-0.31	1.54	1.43
1989	0.34	0.18	0.20	0.38	0.86	0.24	0.10	0.08	0.21	0.03	0.13	-2.18	0.42
1990	0.09	0.13	0.26	0.08	0.10	0.14	0.16	0.14	-0.01	0.15	1.17	-1.90	5.23
1991	0.16	0.13	0.19	0.79	0.03	0.00	-0.13	0.52	0.84	2.15	-0.84	3.09	-6.10
1992	-0.18	-0.06	-0.12	-0.68	-0.47	0.00	-0.69	-0.50	-0.65	-1.94	-0.31	-1.40	0.63
Total 10- Year Change*	***-0.47***	***0.14***	***-0.02***	***0.84***	***-0.03***	***-0.30***	***-1.30***	***0.90***	***-0.98***	***-0.15***	***-1.17***	***-0.85***	***1.61***
1993	0.13	0.06	0.13	0.77	0.60	0.00	0.13	0.20	0.38	0.07	0.52	6.27	1.39
1994	-0.06	-0.02	0.21	-0.11	0.15	0.00	0.31	0.07	-0.22	0.00	0.03	-0.25	5.96
1995	-0.10	-0.01	-0.99	0.32	0.66	0.00	0.46	0.05	-0.78	0.12	0.03	NA	2.67
1996	0.16	0.15	1.12	-0.01	0.27	0.00	0.22	-0.81	0.81	0.22	-0.70	2.75	-1.50
1997	0.05	0.16	-0.89	0.20	0.35	0.00	0.00	0.90	1.92	0.30	1.17	4.22	4.75
1998	0.65	P&A	0.46	-0.04	-0.04	P&A	0.28	0.34	-1.87	0.16	0.10	-0.62	-0.33
1999	-0.21	P&A	0.05	-0.79	-0.91	P&A	-0.33	-0.48	0.06	-0.45	-0.42	-2.93	-5.34
2000	-0.26	P&A	-0.14	-0.54	-1.01	P&A	-0.36	-0.25	-0.60	-0.24	-0.52	-6.07	1.50
2001	0.03	P&A	0.03	0.45	-0.15	P&A	0.08	-0.06	0.09	0.10	-0.12	0.37	5.47
2002	0.16	P&A	0.07	P&A	-0.15	P&A	-0.21	0.70	-0.15	-0.07	-0.18	-0.41	-3.27
Total Change*	***0.08***	***0.48***	***0.03***	***1.09***	***-0.26***	***-0.30***	***-0.72***	***1.56***	***-1.34***	***0.06***	***-1.26***	***2.48***	***12.91***

(1) Hebgen Park Well – No data from 06-1992 to 01-1993, 01-1995 to 09-1996, and 01-1998 to 01-1999.

(*)Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements. NA- no access. P&A- well plugged and abandoned.

irrigation of the park lawn has more of an effect on water-level increases than precipitation, and extends these increases into the fall.

SECTION 6.0 REVIEW OF THE BERKELEY PIT MODEL

MR updated the Berkeley Pit water-level model based upon actual 2002 water-level measurements and HSB-inflow volumes. The model update included water-level increases resulting from MR's suspension of mining and milling operations. The continued suspension of mining activities has resulted in the input of water from the HSB drainage into the Berkeley Pit since July 2000.

Based upon the model updates, it is projected that the critical water level (CWL) of 5,410 feet will be reached at the Anselmo Mine in June 2018, 13 months sooner than predicted in the 2001 model (Czehura, 2003). The model update assumes the continued input of HSB drainage water through December 2003, when the HSB water treatment plant is scheduled for completion. Water from the HSB drainage will then be diverted away from the pit and into the treatment plant. The treated water will be discharged to Silver Bow Creek or used in the mining process, if mining resumes. The model update also includes the disposal of sludge from the HSB water-treatment plant into the pit and additional storm water from the Butte Hill.

The treatment technology and plant-construction time frame for Berkeley Pit water are based upon the schedule listed in the EPA 1994 ROD, and included in the 2002 CD for the Butte Mine Flooding Operable Unit (EPA, 1994). Based upon the current water-level projections, a review of the HSB treatment plant design and operation would begin in June 2014. Any necessary upgrades would have to be completed by June 2016 (Czehura, 2003).

SECTION 7.0 CONCLUSIONS AND SUMMARY

Water-level trends in the alluvial monitoring system were similar to those noted in previous reports at most of the monitored sites. A decrease in water levels continued in a majority of the alluvial wells during 2002. The decline in water levels continued in alluvial monitoring wells to the south and southeast of the September 1998 Berkeley Pit landslide.

Precipitation events still have little or no influence on water levels in the LP-series alluvial wells near the Berkeley Pit and leach pads. Water levels in these wells have continued to decline regardless of precipitation changes.

Water levels in a majority of the alluvial monitoring wells located outside the mine area show a response to seasonal precipitation events. The response time varies from immediate to a two- to three-month lag time. Therefore, the decrease in annual precipitation in the Butte Basin since 1999 probably accounted for a good portion of the overall water-level decrease seen in a number of monitoring wells.

The increased water-level changes in the East Camp bedrock system are independent of precipitation, and are a result of the cessation of long-term mine dewatering activities in 1982. No notable precipitation influence was seen in any of the bedrock wells or underground mines water levels. However, the addition of HSB drainage water into the Berkeley Pit did have a substantial influence on East Camp bedrock water levels. Water levels rose an average of 0.89 foot per month for the first 6 months of 2000, while rising an average of 1.93 feet during the remainder of the year. This increase doubled the amount of the monthly rise. The average 2001 and 2002 monthly water-level rises were about 1.33 feet and 1.29 feet, respectively. The lower rate of water-level rise was probably the result of the lower flow of water from the HSB drainage.

The date the East Camp system water level was predicted to reach the CWL elevation of 5,410 feet was changed by thirteen months from July 2019 to June 2018. The CWL date is assumed to be the date the 5,410-foot elevation would be reached at the Anselmo Mine. The Anselmo Mine is the anticipated compliance point in order to keep the Berkeley Pit the lowest point in the East Camp bedrock-mine system. This will ensure that all water in the historic underground mine system will continue to flow towards the Berkeley Pit.

The pumping of ground water in the West Camp System continues to control water levels in this system. The volume of water pumped during 2002 was less than in previous years; thus, water levels rose about 1.5 feet throughout this system and are now about 10 feet below the maximum-allowable level.

Results of the 2002 water-level monitoring continue to show that the current monitoring program is adequate for ensuring that contaminated bedrock ground water is flowing into the Berkeley Pit, and that West Camp water levels are being sufficiently controlled by West Camp pumping operations. These are two of the main environmental concerns associated with the flooding of Butte's historic underground mines and the Berkeley Pit.

Monitoring wells in the alluvial aquifers associated with the Mine Flooding Operable Unit continue to show a wide range of concentrations, both spatially and temporally. As is the case for the last few years, the AMC-series wells show a wide variation and few trends with respect to the concentration of dissolved constituents. The LP-series wells show a continuation of previous trends in most wells for most constituents; a few wells may show an initial reversal of some concentration trends.

In several cases, chemistry data from the East Camp mines show a notable departure from recent trends. Although no problems could be identified with sampling methods or lab analytical procedures, sample depth may have influenced the most recent data.

Recent data from the West Camp monitoring sites generally indicate a continuation of recent trends in water quality. Although the concentrations of several dissolved constituents trend upward, they are generally well below values observed during initial flooding. Data from the Emma shaft appear to indicate a notable departure from recent trends and an increasing difference in water quality compared to the Travona Mine.

Water-quality trends at monitoring sites of the Outer Camp remain unremarkable. As with the overall trend of water levels, the water chemistry at these sites tends to reflect stable conditions.

Based upon the review of data collected over more than 20 years, the monitoring program was revised during the CD negotiations. Table 7.0.1 contains a listing of the Post-RI/FS monitoring sites, and the 2003 CD schedule. Minor modifications were made in both the frequency and sites monitored for both water level and water quality. Through conditions contained in the CD, a stable, long-term monitoring program is in place and will be maintained.

Table 7.0.1 Comparison of Post RI/FS Sample Sites and Schedule and the 2003 Consent Decree Schedule.

Butte Mine Flooding Monitoring Sites		Current Program Well Monitoring Frequency	**Consent Decree Monitoring Frequency**	Current Program Water Quality	**Consent Decree Water Quality Frequency**
East Camp Mines(2)	Anselmo	M	**M**	SA/Annual	**Annual**
	Belmont		**--------**		
	Belmont Well #2	M	**1/4ly**	SA/Annual	**NS**
	Granite Mountain	M	**1/4ly**	SA/Annual	**NS**
	Kelley	M	**M**	SA/Annual	**Annual**
	Lexington	M	**1/4ly**	NS	**NS**
	Missoula	M	**Drop**		
	Pilot Butte	M	**1/4ly**	Annual	**NS**
	Steward	M	**M**	NS	**Annual**
	Berkeley Pit	M	**M**	NS	**Twice/3Depths**
	HSB(3)	C	**C**	Bi-Weekly	**M**
	Continental Pit(3)		**M**	NS	**Twice/yr.**
RI/FS Wells - Bedrock	A	C	**C**	Semi-A	**Semi-A**
	B	M	**M**	Semi-A	**Semi-A**

	C	C	**C**	Semi-A	**Semi-A**
	D-1	C	**1/4ly**	Semi-A	**Annual**
	D-2	C	**1/4ly**	Semi-A	**Annual**
	E	M	**Annual**	Semi-A	**2yrs**
	F	M	**Annual**	Semi-A	**2yrs**
	G	C	**C**	Semi-A	**Annual**
	H	P&A		Semi-A	**NS/P&A**
	J	M	**1/4ly**	Semi-A	**Annual**
DDH Wells	DDH-1	M	**1/4ly**	NS	**NS**
	DDH-2	M	**1/4ly**	NS	**NS**
	DDH-4	M	**Drop**	NS	**NS/Drop**
	DDH-5	P&A		NS	**NS/P&A**
	DDH-8	M	**1/4ly**	NS	**NS**
LP Wells	LP-01	C	**1/4ly**	NS	**NS**
	LP-02	M	**1/4ly**	NS	**NS**
	LP-03	M	**1/4ly**	NS	**NS**
	LP-04	M	**1/4ly**	NS	**NS**
	LP-05	M	**1/4ly**	NS	**NS**
	LP-06	C	**1/4ly**	NS	**NS**
	LP-07	M	**1/4ly**	NS	**NS**
	LP-08	M	**M**	Semi-A	**Annual**
	LP-09	M	**1/4ly**	Semi-A	**Annual**
	LP-10	M	**M**	Semi-A	**Semi-A**
	LP-11	M	**P&A**	Semi-A	**NS/P&A**
	LP-12	C/M	**M**	Semi-A	**Semi-A**
	LP-13	C/M	**M**	Semi-A	**Semi-A**
	LP-14	C	**C**	Semi-A	**Semi-A**
	LP-15	M	**M**	Semi-A	**Semi-A**
	LP-16	C/M	**M**	Semi-A	**Semi-A**
	LP-17	M	**1/4ly**	Semi-A	**Annual**
	97-1	M	**1/4ly**	NS	**NS**
	97-2	M	**1/4ly**	NS	**NS**
	97-3	M	**1/4ly**	NS	**NS**
	97-4	M	**1/4ly**	NS	**NS**
AMC Wells	AMC-5	M	**1/4ly**	Semi-A	**Annual**
	AMC-6	C	**C**	Semi-A	**Semi-A**
	AMC-8	C	**C**	Semi-A	**Semi-A**
	AMW-8		**1/4ly**	NS	**NS/Annual**
	AMC-10	M	**1/4ly**	Semi-A	**Semi-A**
	AMC-11	M	**Drop**	Semi-A	**NS/Drop**
	AMC-12	M	**1/4ly**	SA/Annual	**Annual**
	AMC-13	M	**1/4ly**	SA/Annual	**NS**
	AMC-15	M	**1/4ly**	SA/Annual	**2yrs**
	AMW-22		**1/4ly**	NS	**NS/Annual**
	AMC-23	C/M	**Drop**	SA/Annual	**NS/Drop**
	AMC-24	C/M	**Drop**	SA/Annual	**NS/Drop**
GS Wells	GS-41S	M	**C**	NS	**Annual**
	GS-41D	M	**C**	NS	**Annual**
	GS-44S	M	**C**	NS	**Annual**
	GS-44D	C	**C**	NS	**Annual**
	GS-46S	M	**C**	NS	**Annual**
	GS-46D	C	**C**	NS	**Annual**
Park Wells	Chester Steele	C	**1/4ly**	Semi-A	**Annual**

	Hebgen	M	**1/4ly**	Semi-A	**NS**
	Belmont #1	M	**1/4ly**	NS	**NS**
	Parrott	C	**1/4ly**	NS	**Annual**
West Camp Mines	Emma	M	**1/4ly**	Annual	**Annual**
	Ophir	M	**1/4ly**	Annual	**Annual**
	Travona	M	**1/4ly**	M-Pumping	**Annual**
West Camp Wells	WCPW-1	No	**No**	1/4ly-Pumping	**1/4ly-Pumping**
	BMF96-1D	C	**C**	Semi-A	**NS**
	BMF96-1S	C	**C**	Semi-A	**NS**
	BMF96-2	C	**1/4ly**	Semi-A	**NS**
	BMF96-3	No	**1/4ly**	NS	**NS**
	BMF96-4	C	**C**	Semi-A	**Annual**
Outer Camp Mines	Orphan Boy	M/ 1/4ly	**Replace**	Annual	**NS**
	Orphan Girl		**M**		**Annual**
	Marget Ann	M/ 1/4ly	**1/4ly**	SA/Annual	**2yrs**
Outer Camp Wells	S-4	M	**1/4ly**	Semi-A	**NS**
	Tech Well	No	**1/4ly**	NS	**2yrs**
	Seep	M	**Semi-A**	M	**Semi-A**
Domestic Wells	92-2	M	**Drop**	NS	**NS**
	93-4	M	**Drop**	NS	**NS**
	93-7	M	**Drop**	NS	**NS**
	93-8	M	**Drop**	NS	**NS**
	93-9	M	**Drop**	NS	**NS**
	93-10	M	**Drop**	NS	**NS**
	93-12	M	**Drop**	NS	**NS**
	93-20	M	**Drop**	NS	**NS**
	93-22	M	**Drop**	NS	**NS**
	93-23	M	**Drop**	NS	**NS**
	93-24	M	**Drop**	NS	**NS**
	93-25	M	**Drop**	NS	**NS**
	93-26	M	**Drop**	NS	**NS**
	MPC	M	**Drop**	NS	**NS**

(1) Additional alluvial monitoring wells will be installed to replace the currently monitored domestic wells, which will be dropped from the program.

(2) The safety of each mine will be reviewed and if unsafe conditions exist, repairs will be made, or another site will be substituted for the unsafe location.

(3) MBMG monitoring and sampling will occur only when pumping and treatment is not taking place. Otherwise, monitoring and sampling will be part of the water treatment plant operations.

(4) MR97 series wells will be monitored until steady state conditions occur. A review of continued monitoring will be undertaken at that time.

C - Continuous
M - Monthly
NS - No Sampling
P&A - Plugged and Abandoned
SA - Semi-A, Semi-Annual
1/4ly - Quarterly

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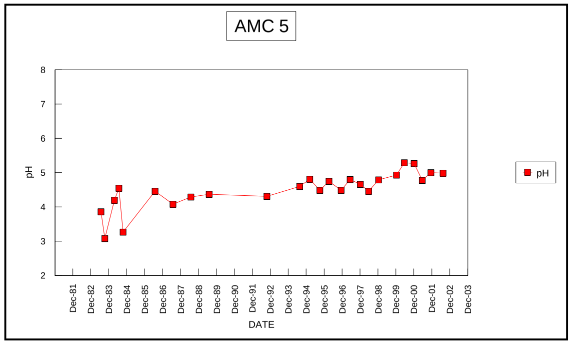
APPENDIX A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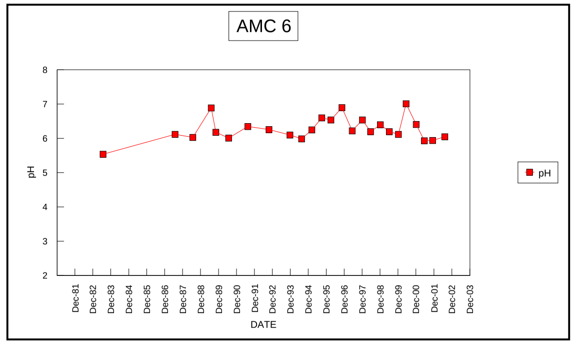
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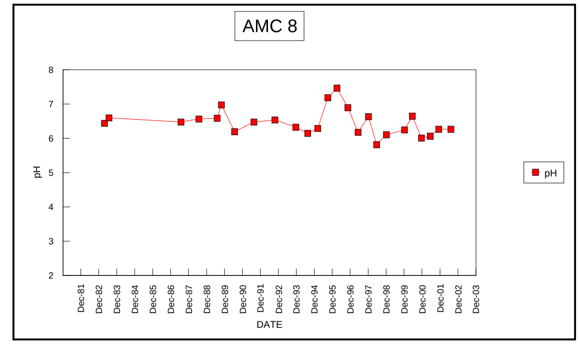
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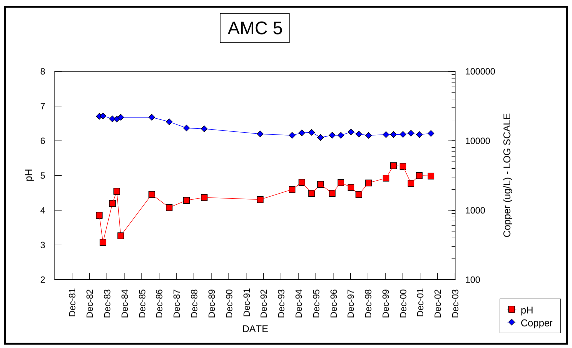
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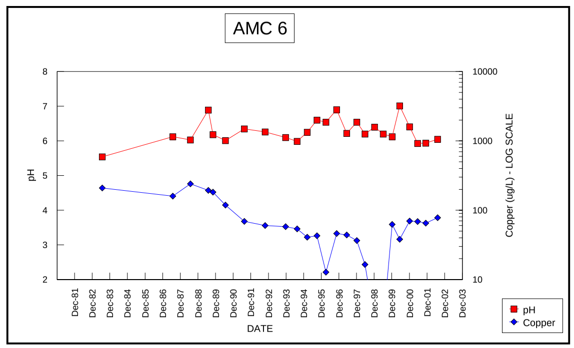
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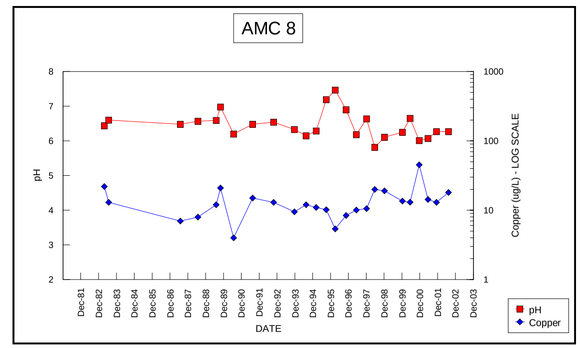
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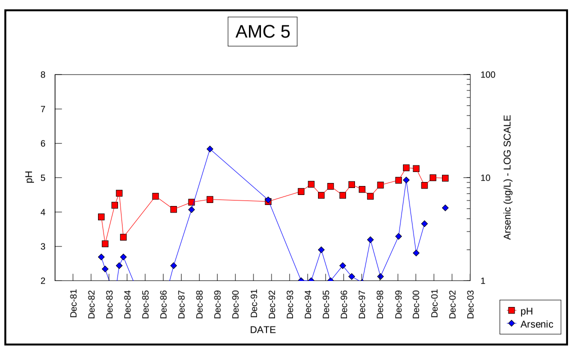
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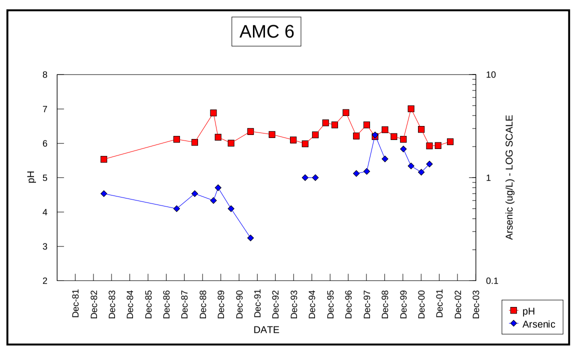
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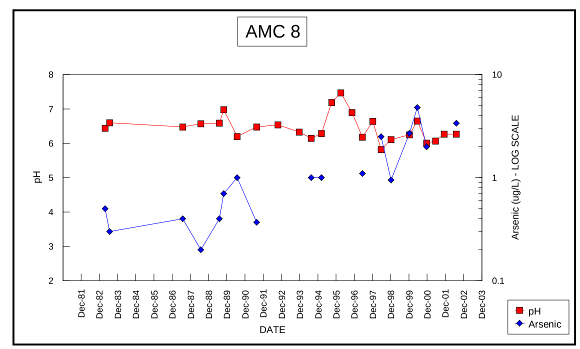
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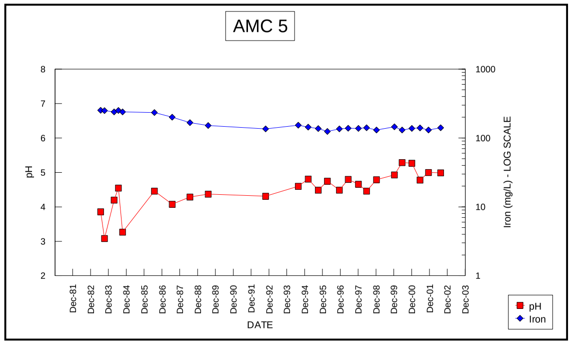
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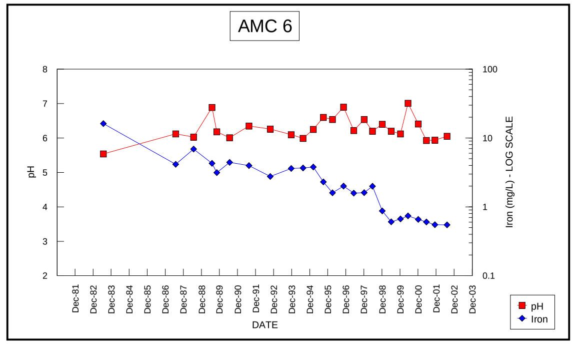
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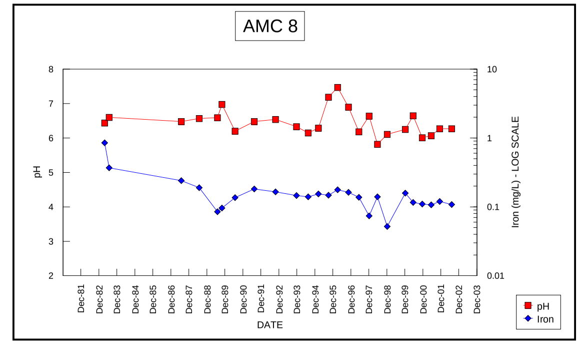
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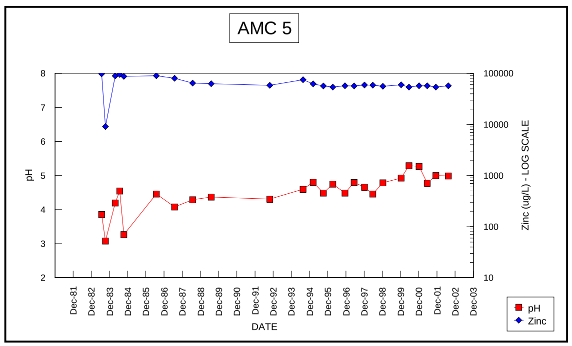
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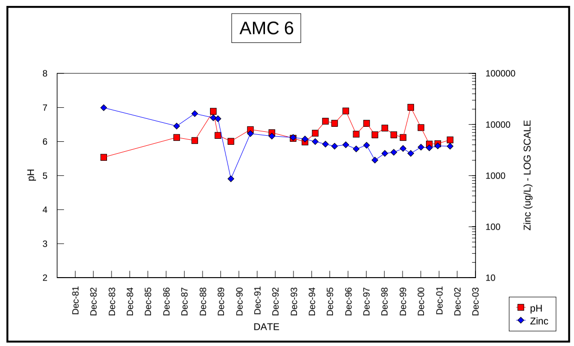
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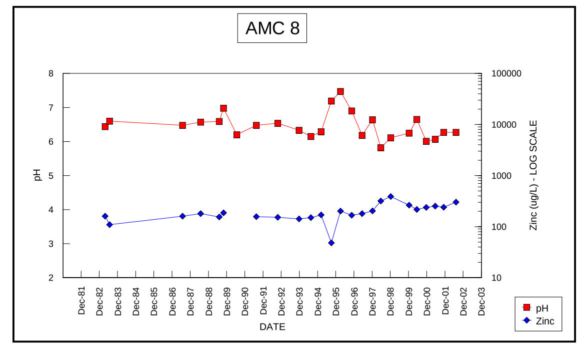
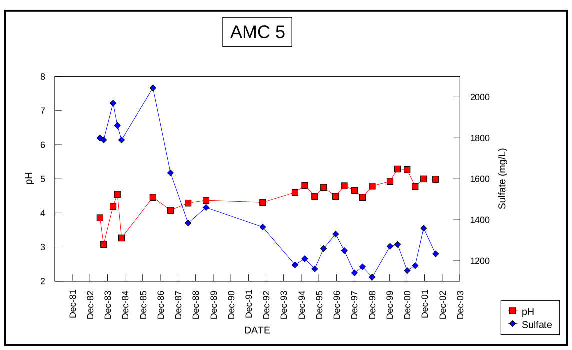
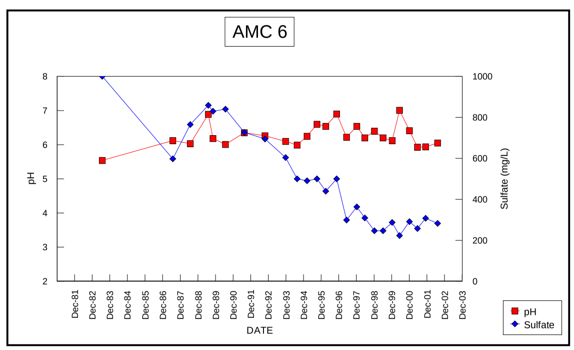
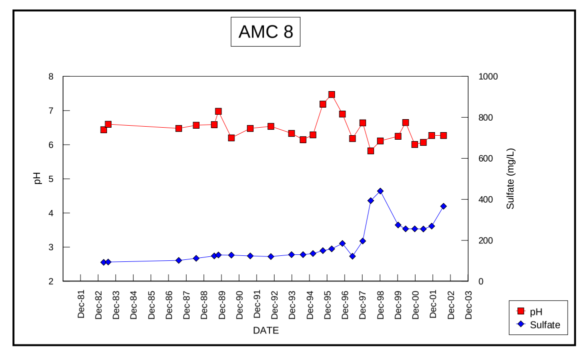
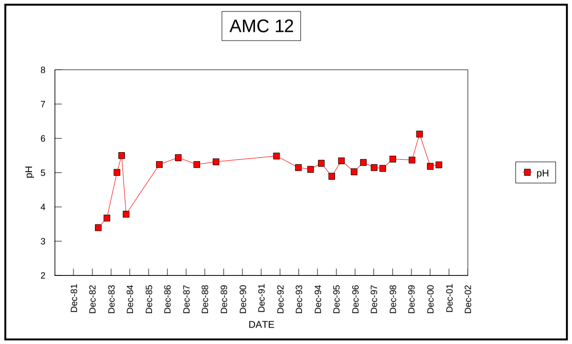
pH
Zinc

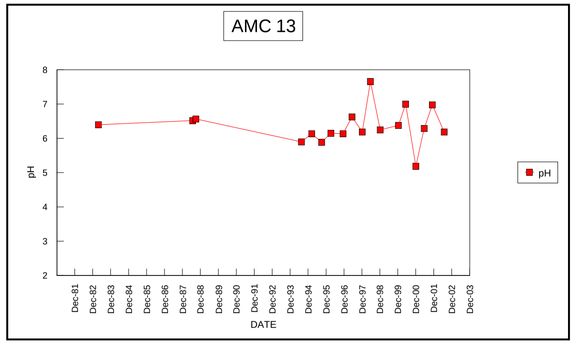

AMC 8
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

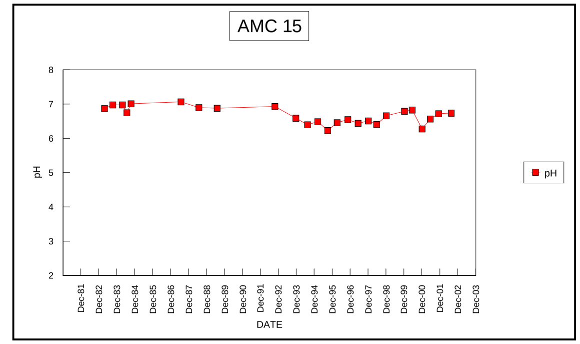

AMC 5
pH
Sulfate (mg/L)
DATE
pH
Sulfate

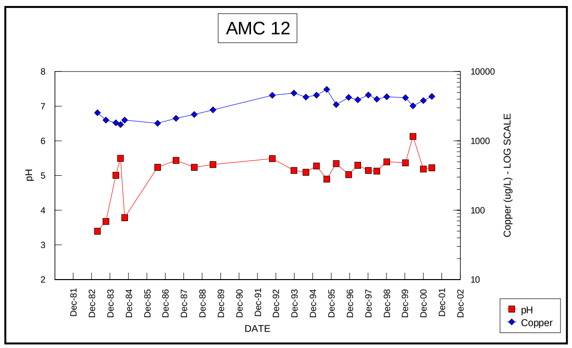

AMC 6
pH
Sulfate (mg/L)
DATE
pH
Sulfate

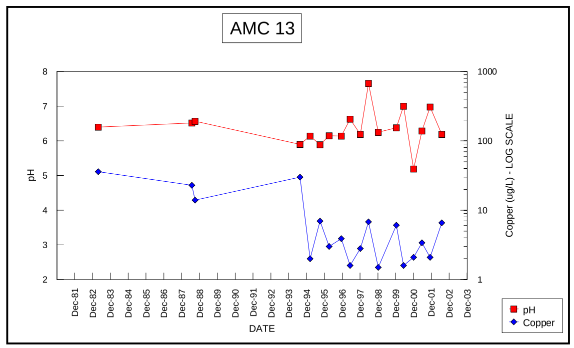

AMC 8
pH
Sulfate (mg/L)
DATE
pH
Sulfate

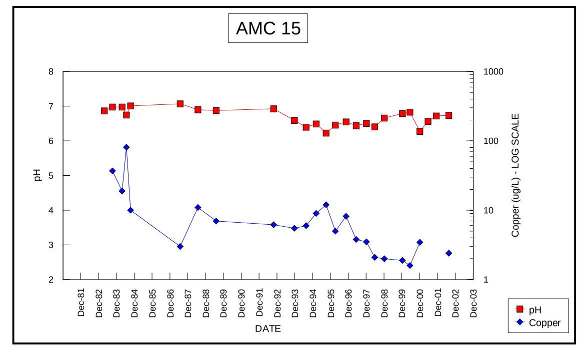

AMC 12
pH
DATE
pH

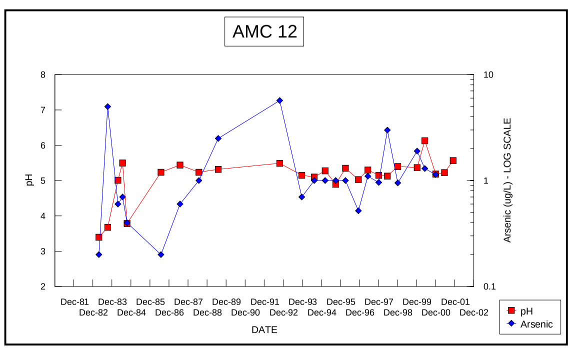

AMC 13
pH
DATE
pH

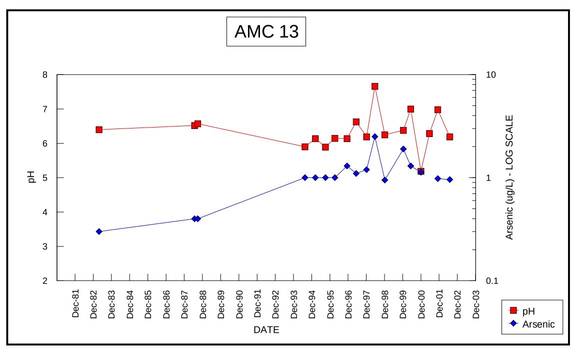

AMC 15
pH
DATE
pH

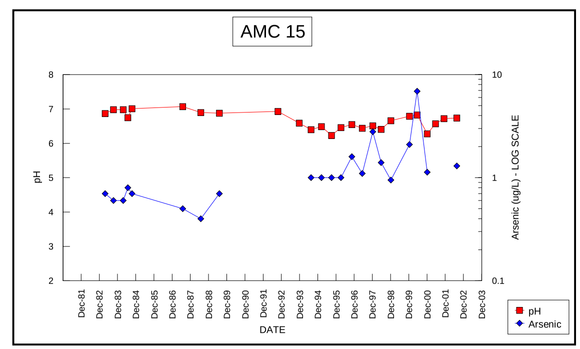

AMC 12
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

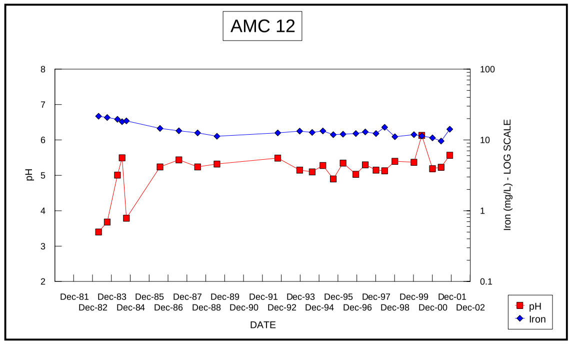

AMC 13
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

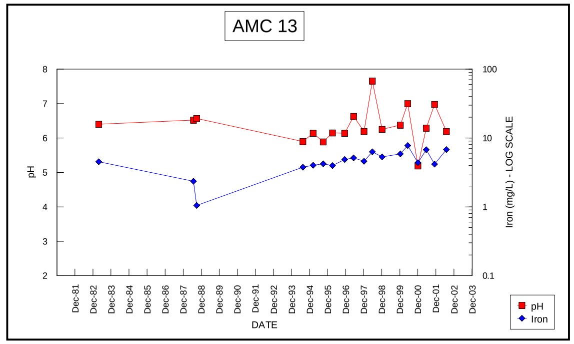

AMC 15
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

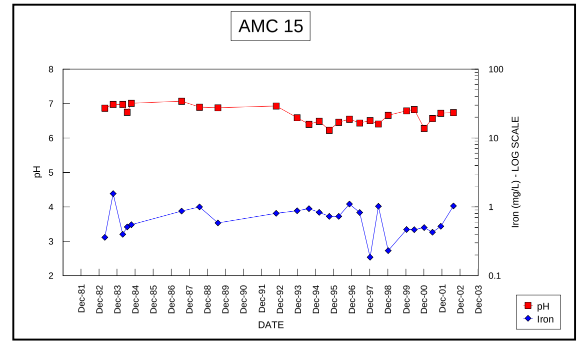

AMC 12
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

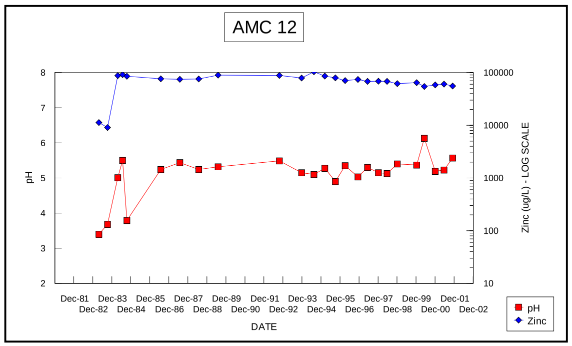

AMC 13
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

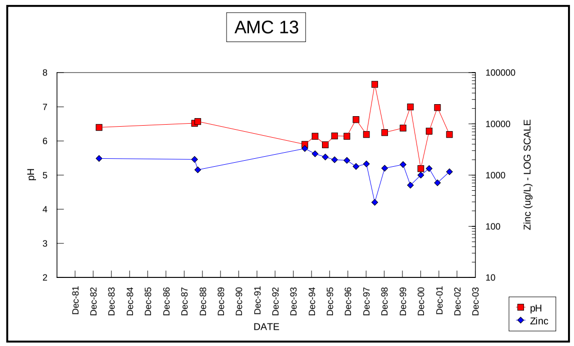

AMC 15
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

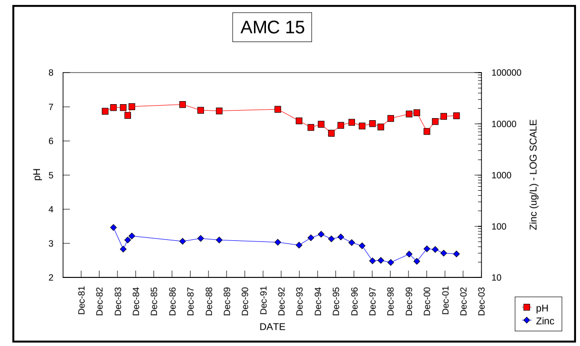

AMC 12
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

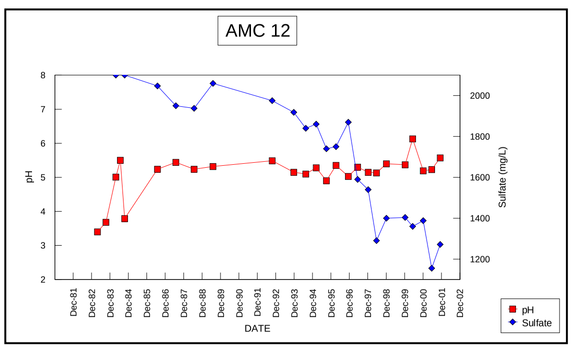

AMC 13
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

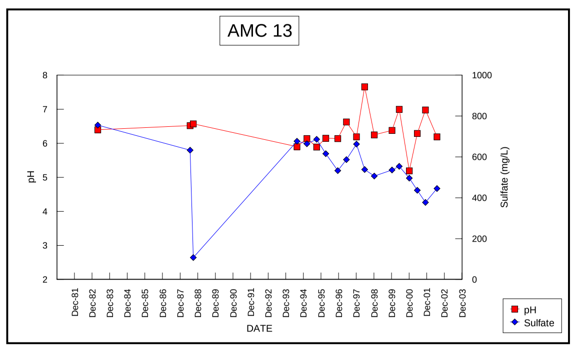

AMC 15
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

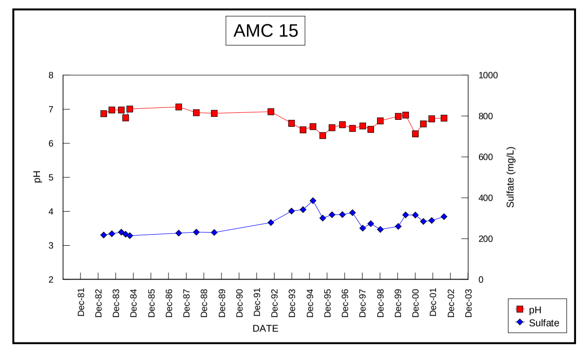

AMC 12
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

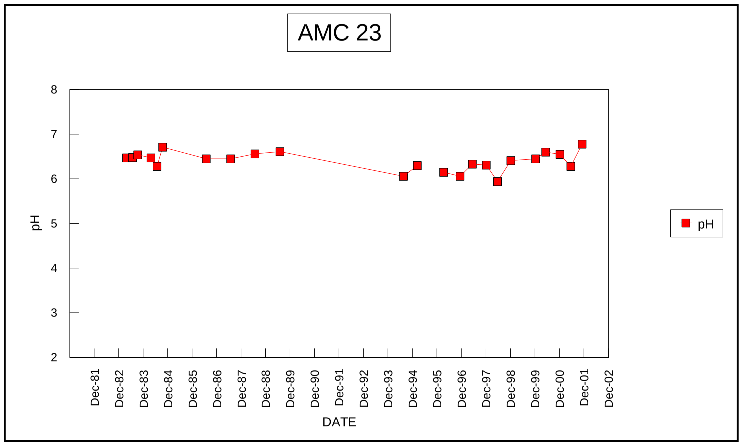

AMC 13
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

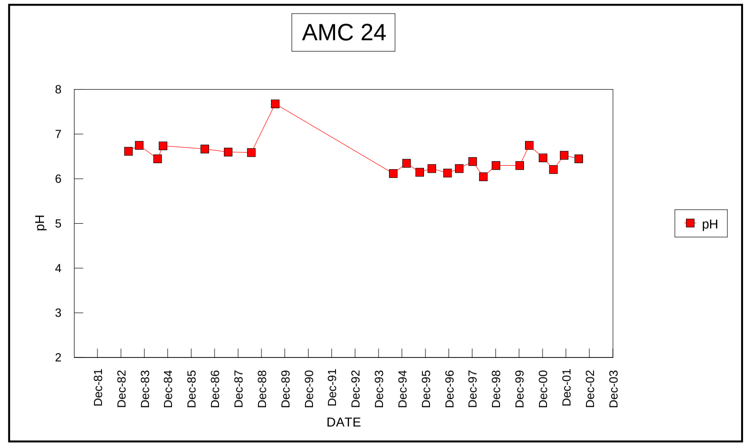

AMC 15
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

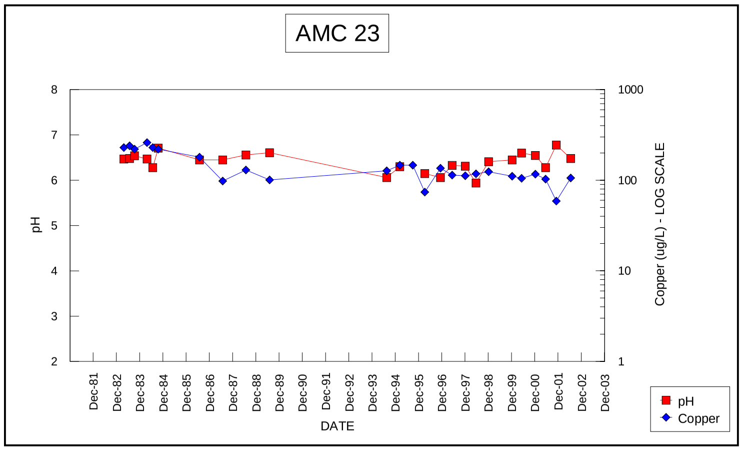

AMC 12
pH
Sulfate (mg/L)
DATE
pH
Sulfate

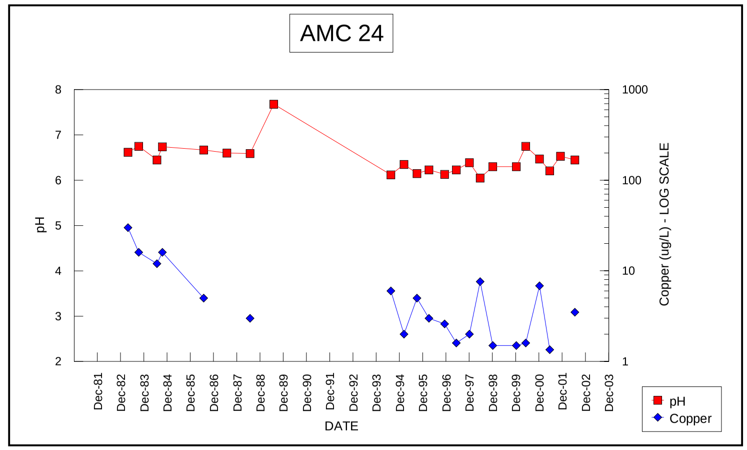

AMC 13
pH
Sulfate (mg/L)
DATE
pH
Sulfate

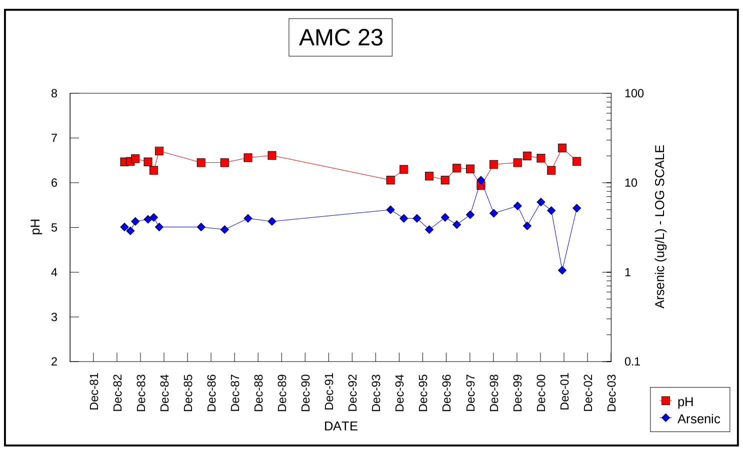

AMC 15
pH
Sulfate (mg/L)
DATE
pH
Sulfate

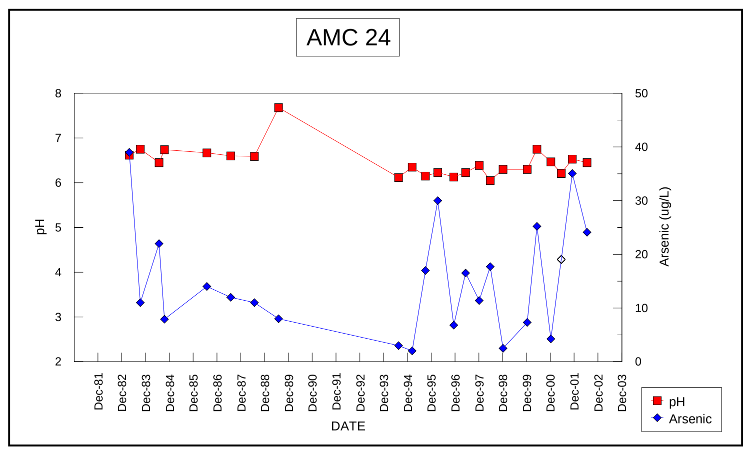

AMC 23
pH
DATE
pH

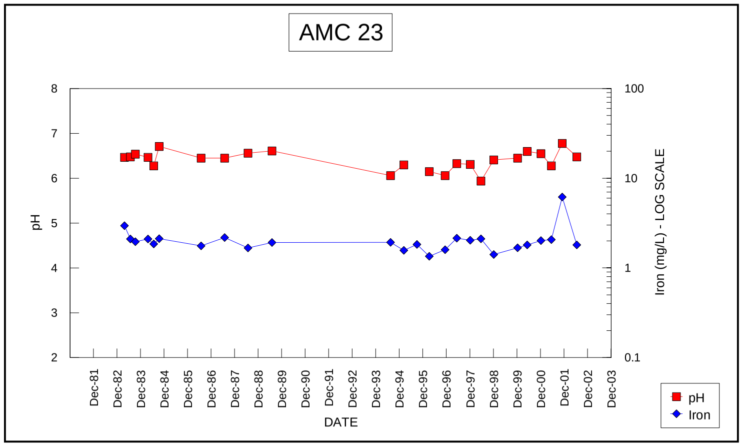

AMC 24
pH
DATE
pH

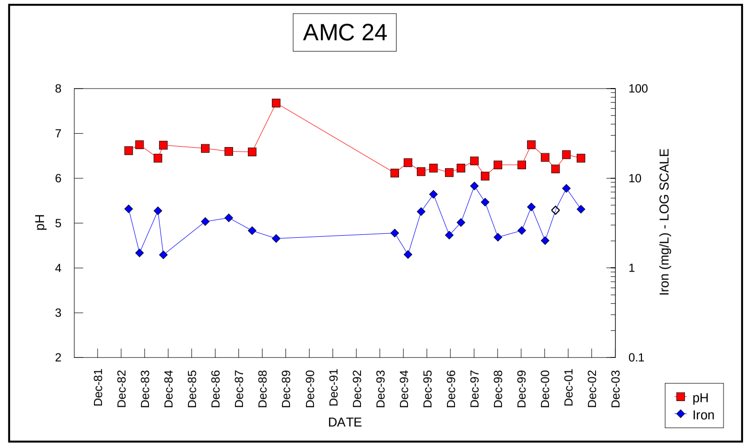

AMC 23
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

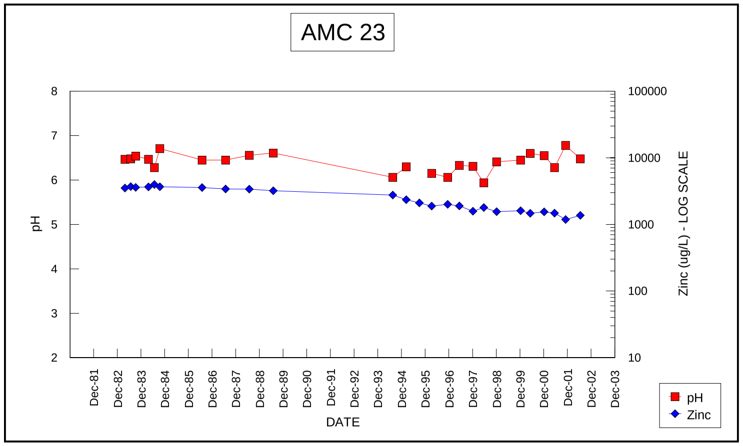

AMC 24
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

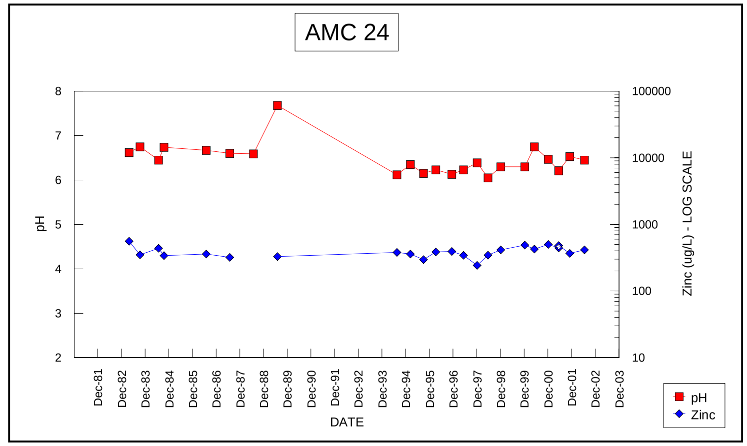

AMC 23
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

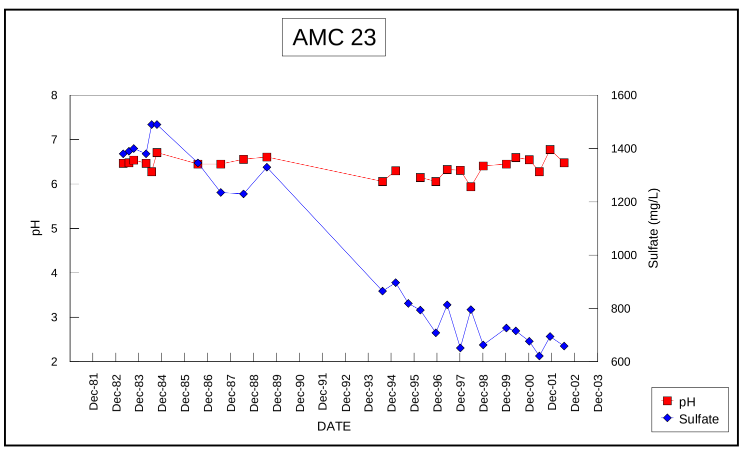

AMC 24
pH
Arsenic (ug/L)
DATE
pH
Arsenic

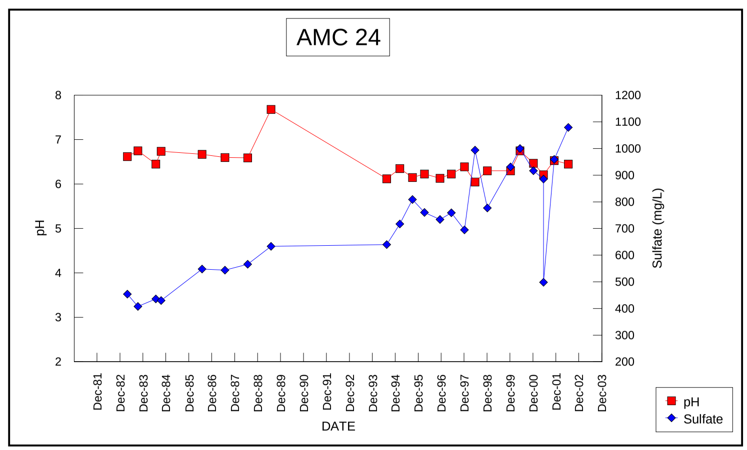

AMC 23
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron


AMC 24
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

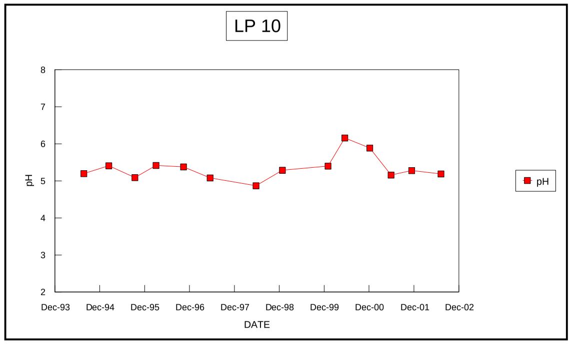

AMC 23
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

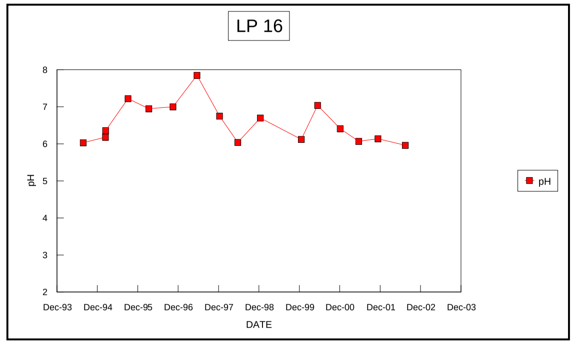

AMC 24
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

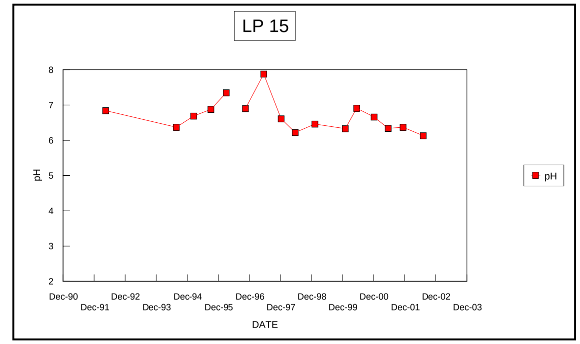

AMC 23
pH
Sulfate (mg/L)
DATE
pH
Sulfate

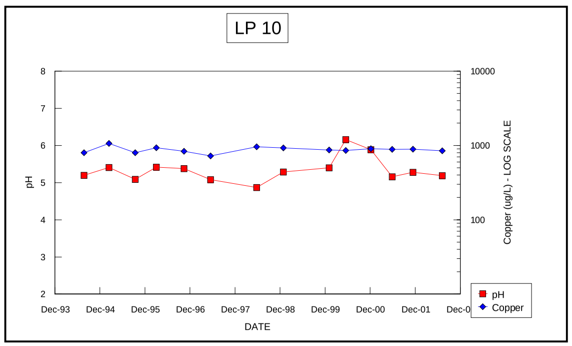

AMC 24
pH
Sulfate (mg/L)
DATE
pH
Sulfate

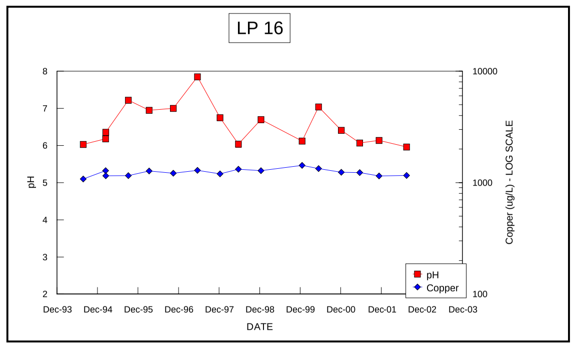
APPENDIX B

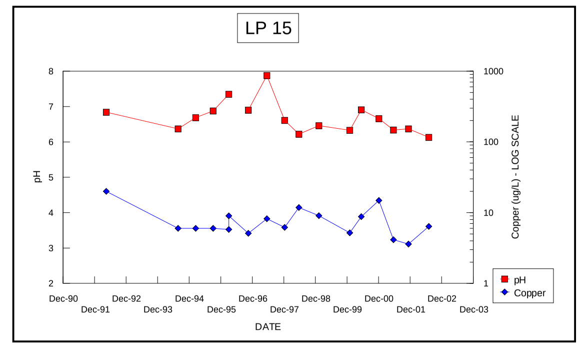

LP 10
pH
DATE
pH

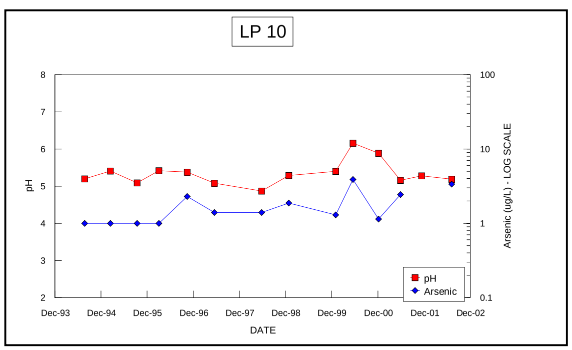

LP 16
pH
DATE
pH

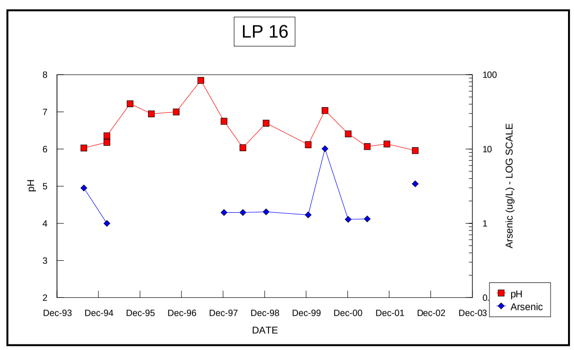

LP 15
pH
DATE
pH

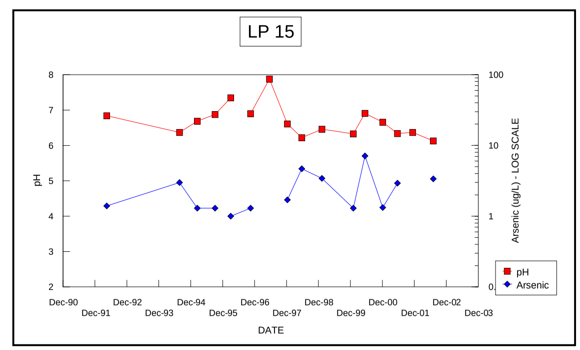

LP 10
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

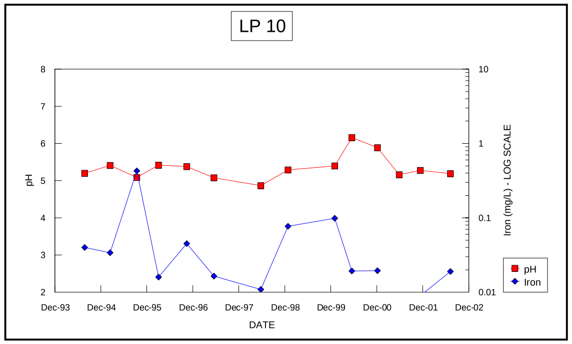

LP 16
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

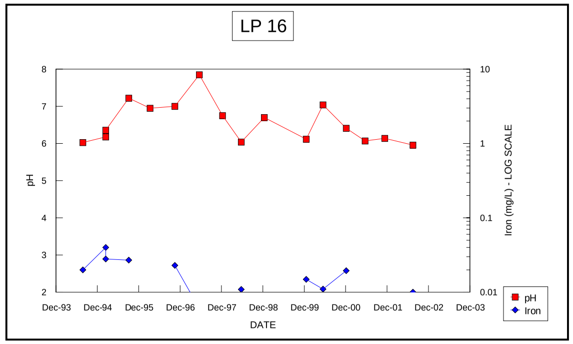

LP 15
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

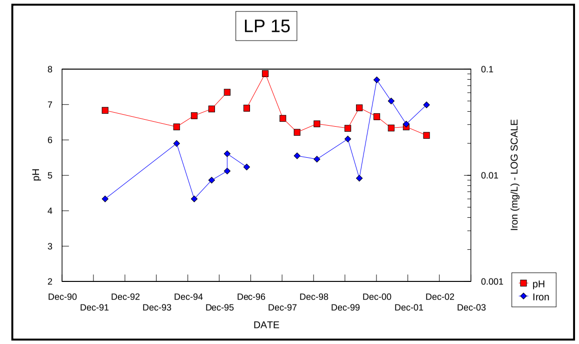

LP 10
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

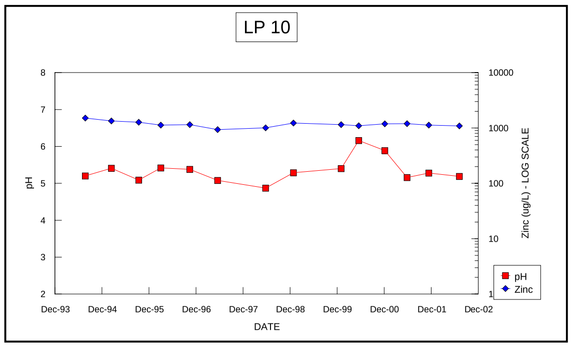

LP 16
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

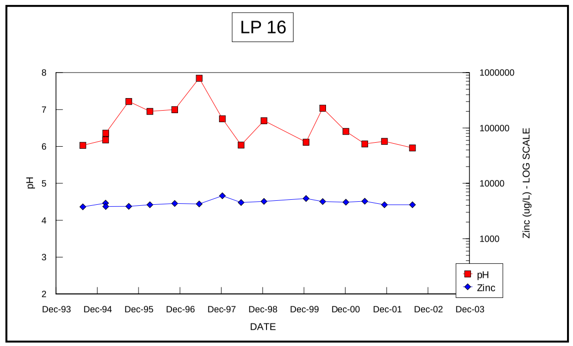

LP 15
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

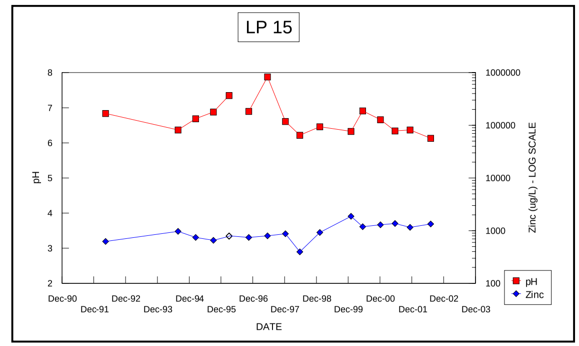

LP 10
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

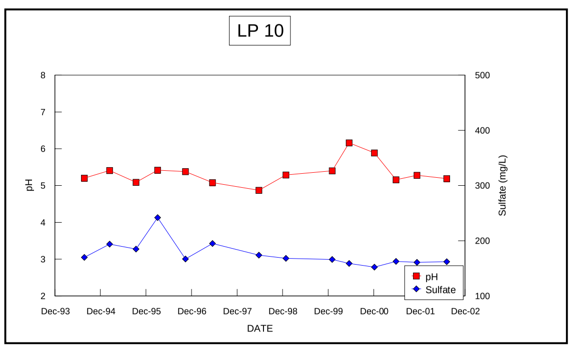

LP 16
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

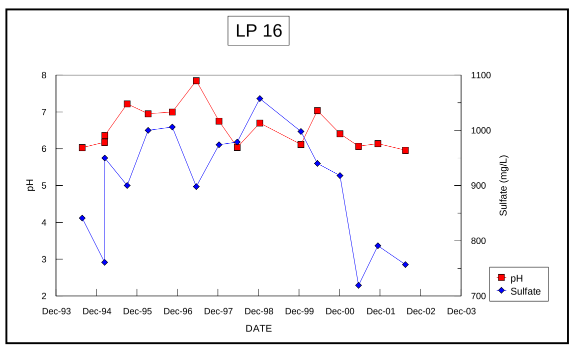

LP 15
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

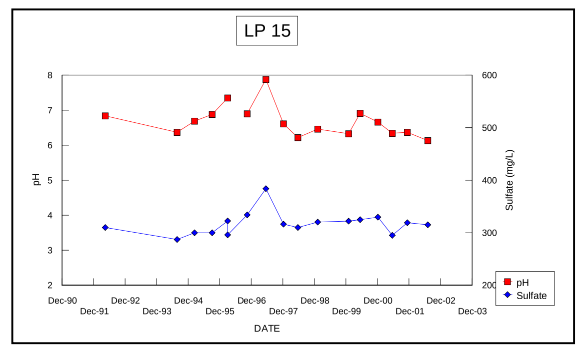

LP 10
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

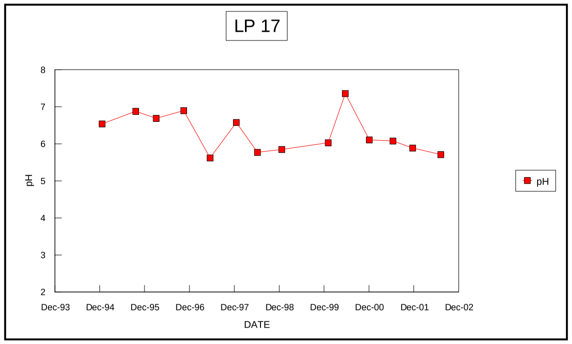

LP 16
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

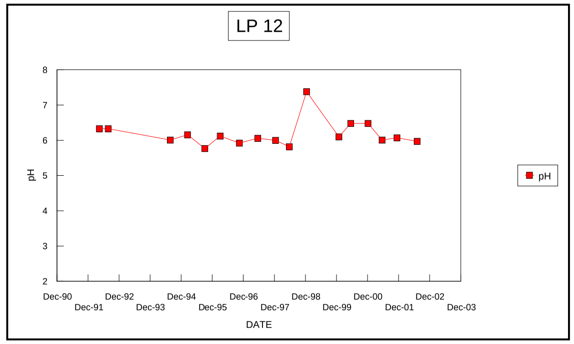

LP 15
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

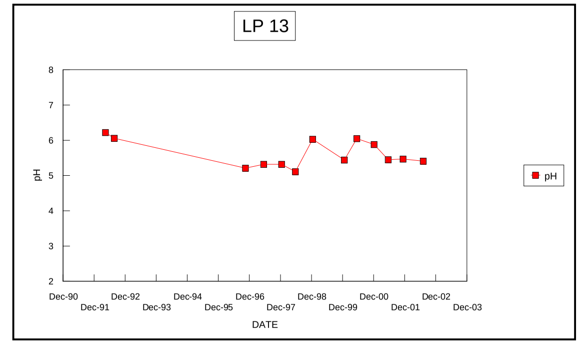

LP 10
pH
Sulfate (mg/L)
DATE
pH
Sulfate

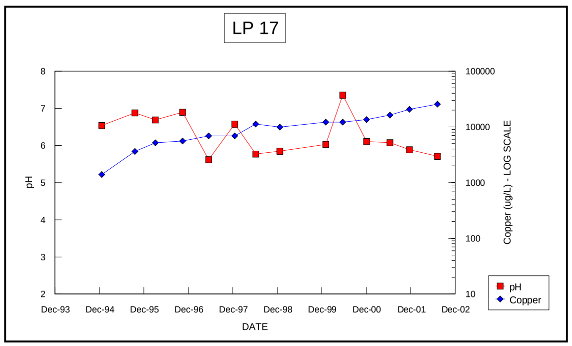

LP 16
pH
Sulfate (mg/L)
DATE
pH
Sulfate

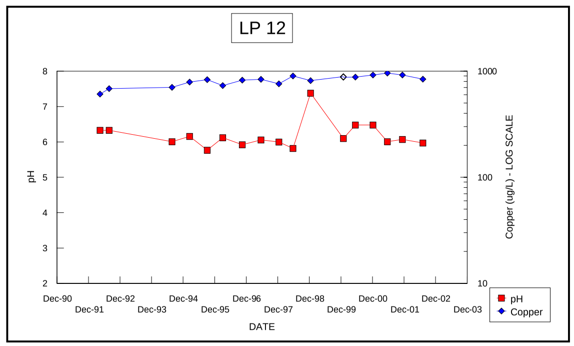

LP 15
pH
Sulfate (mg/L)
DATE
pH
Sulfate

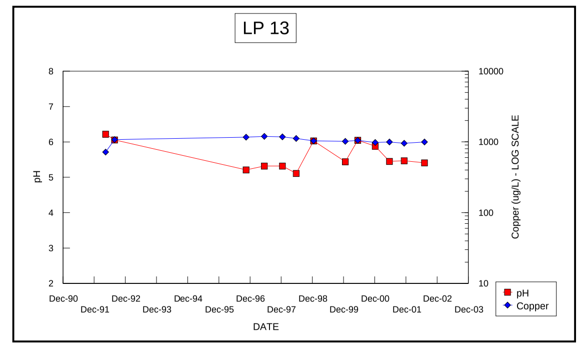

LP 17
pH
DATE
pH

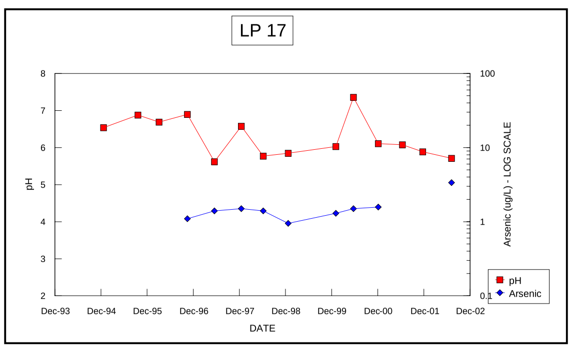

LP 12
pH
DATE
pH

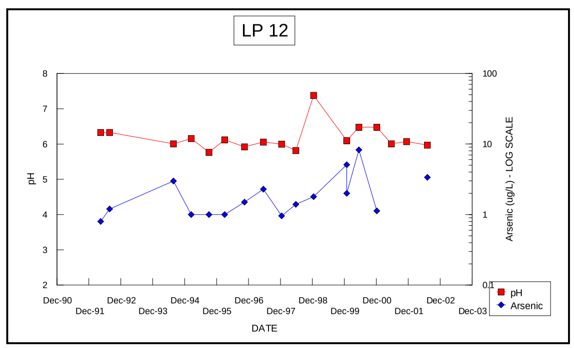

LP 13
pH
DATE
pH

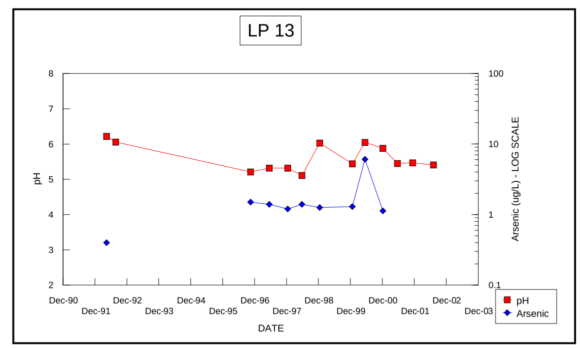

LP 17
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

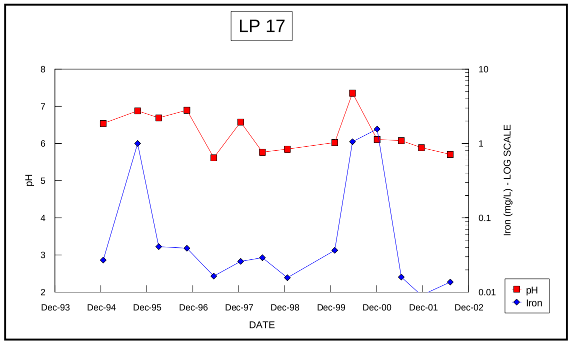

LP 12
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

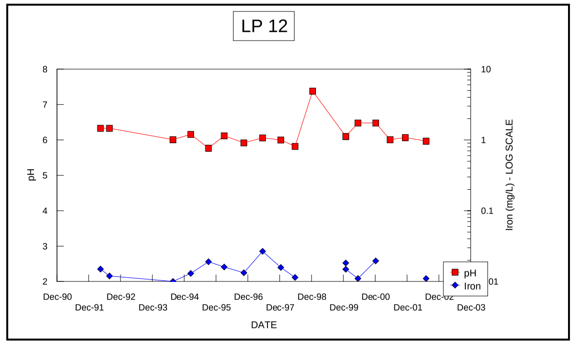

LP 13
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

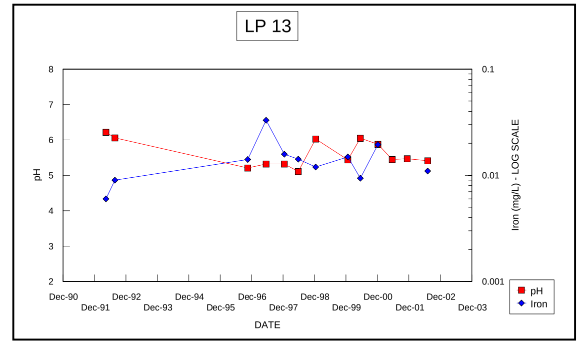

LP 17
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

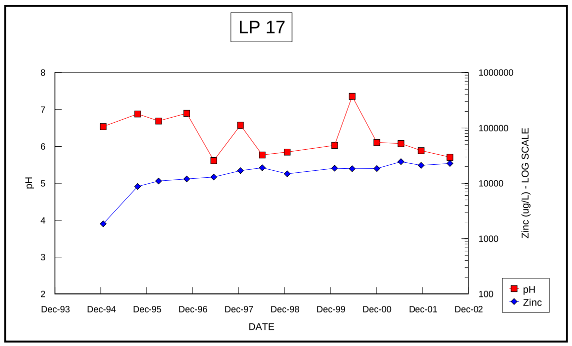

LP 12
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

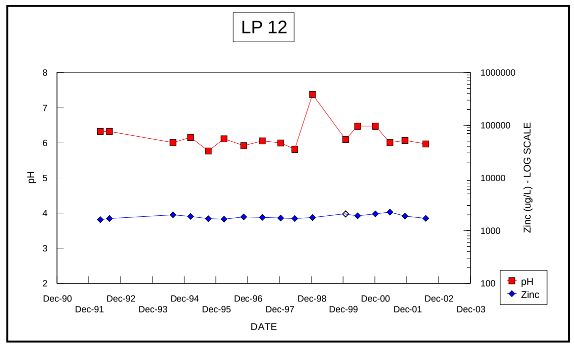

LP 13
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

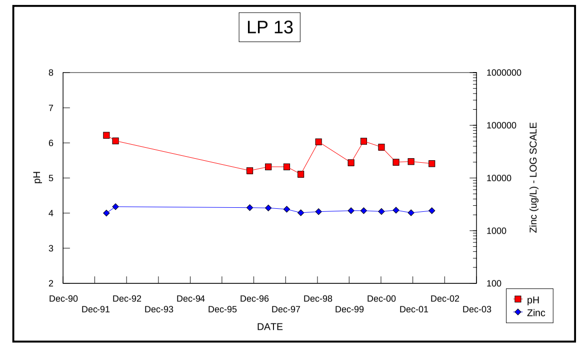

LP 17
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

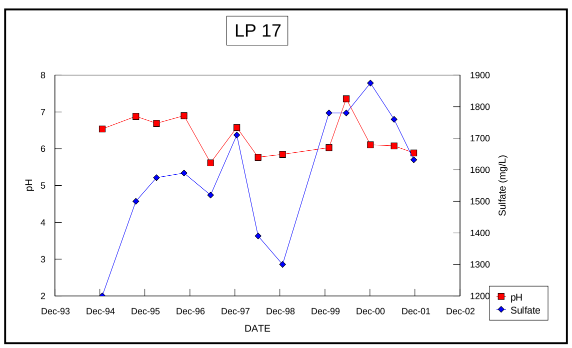

LP 12
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

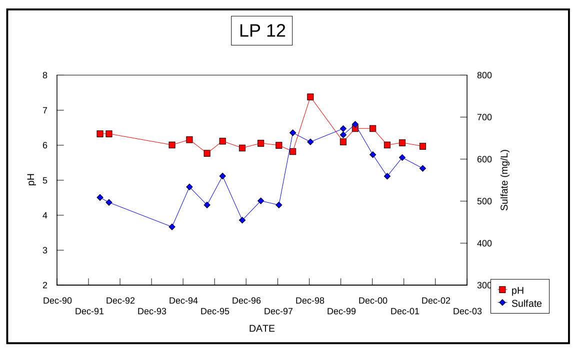

LP 13
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

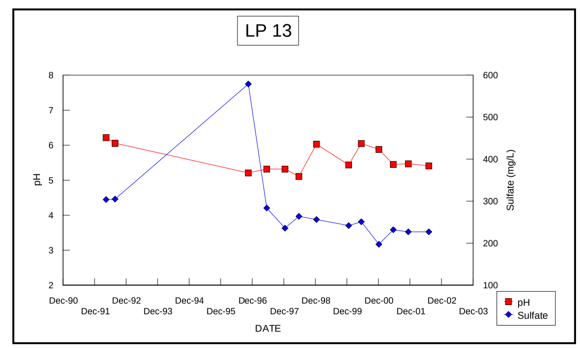

LP 17
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

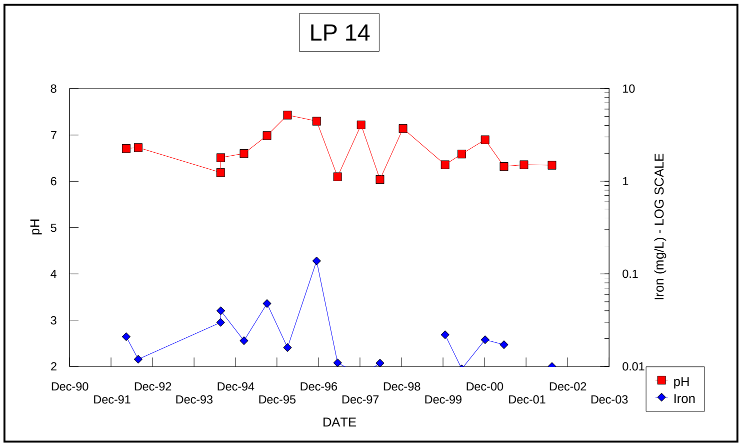

LP 12
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

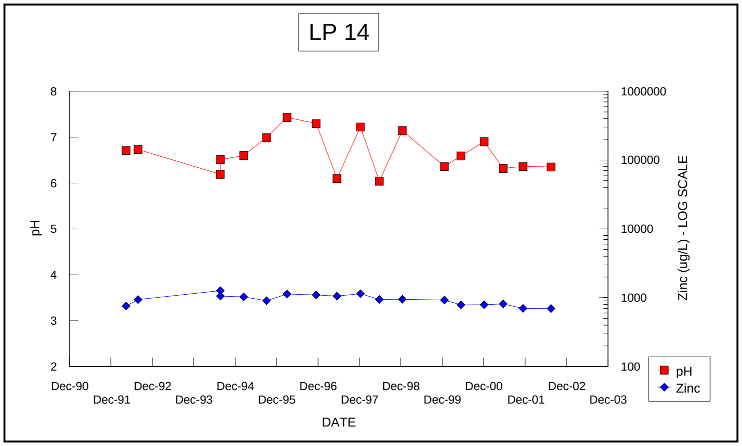

LP 13
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

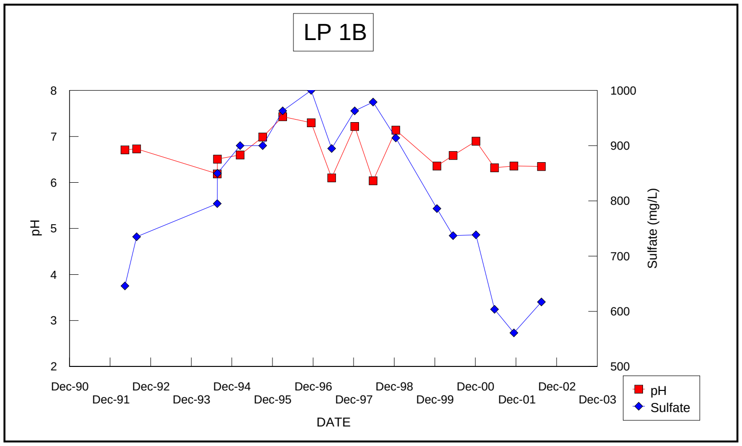

LP 17
pH
Sulfate (mg/L)
DATE
pH
Sulfate

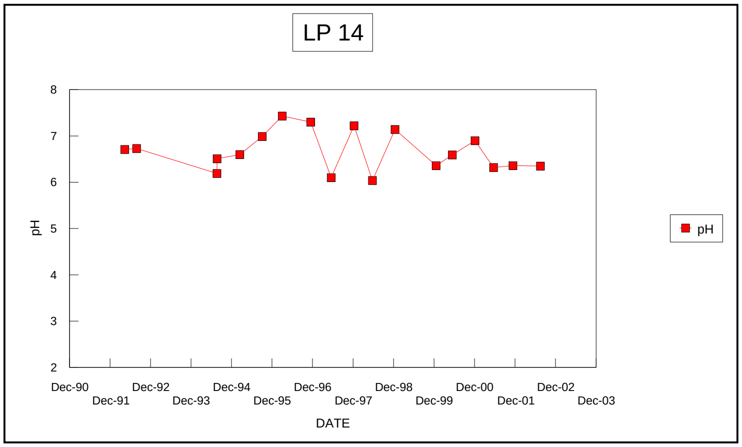

LP 12
pH
Sulfate (mg/L)
DATE
pH
Sulfate

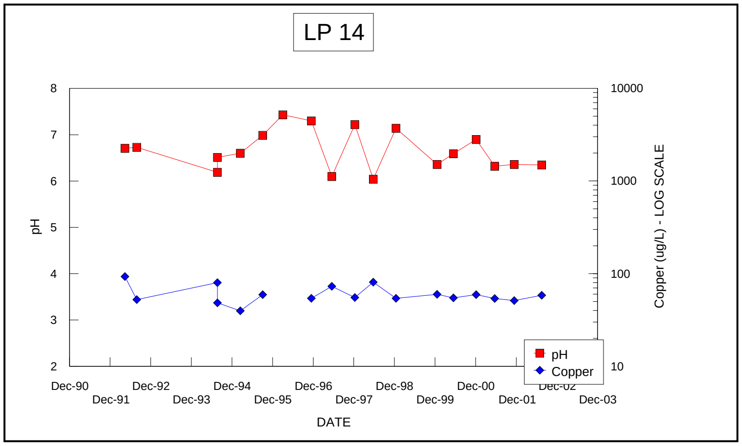

LP 13
pH
Sulfate (mg/L)
DATE
pH
Sulfate

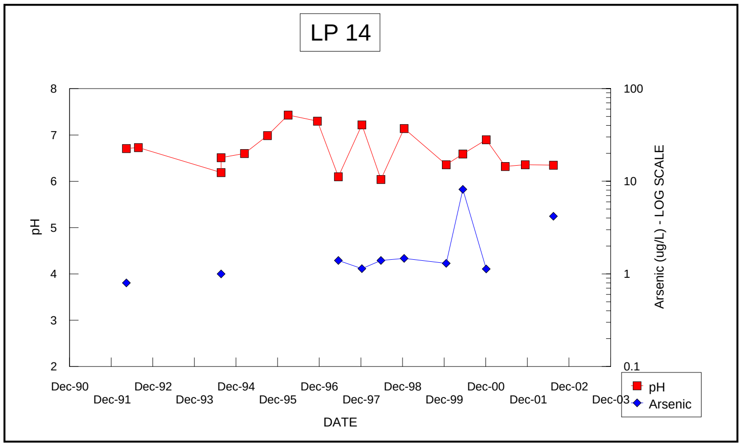

LP 14
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron


LP 14
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

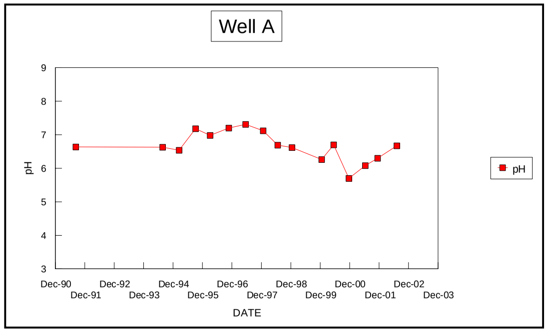

LP 1B
pH
Sulfate (mg/L)
DATE
pH
Sulfate

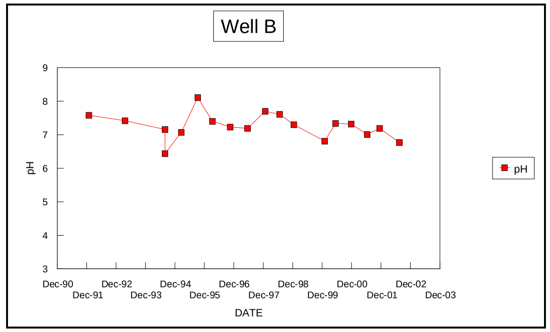

LP 14
pH
8
7
6
5
4
3
2
Dec-90
Dec-91
Dec-92
Dec-93
Dec-94
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
DATE
pH

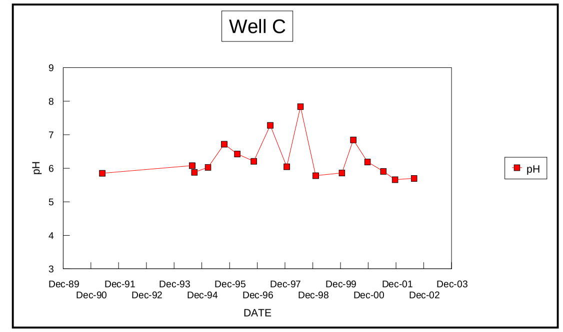

LP 14
pH
Copper (ug/L) - LOG SCALE
10000
1000
100
10
DATE
pH
Copper

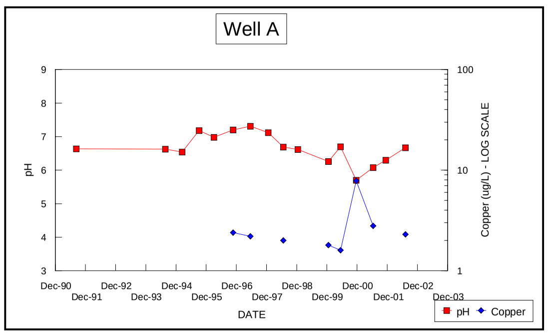

LP 14
pH
Arsenic (ug/L) - LOG SCALE
100
10
1
0.1
DATE
pH
Arsenic

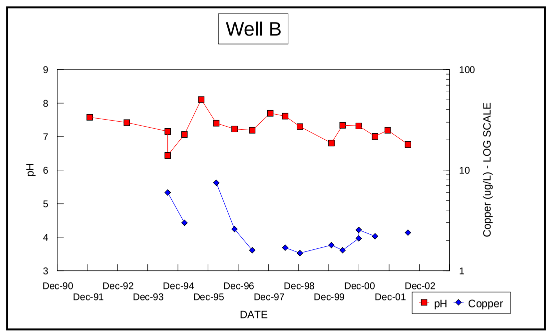
APPENDIX C

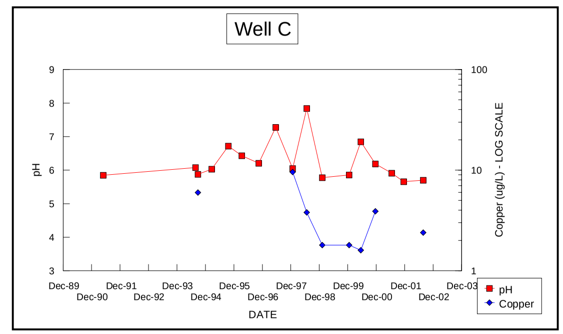

Well A
pH
DATE
pH

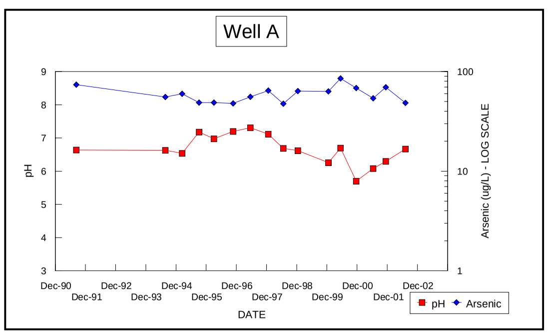

Well B
pH
DATE
pH

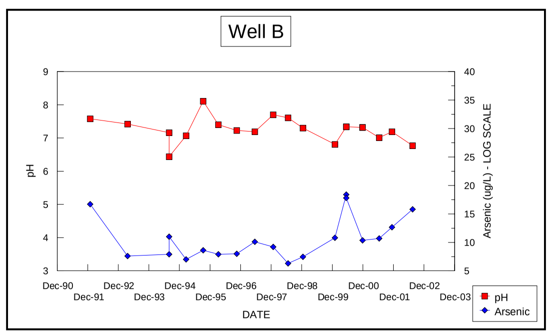

Well C
pH
DATE
pH

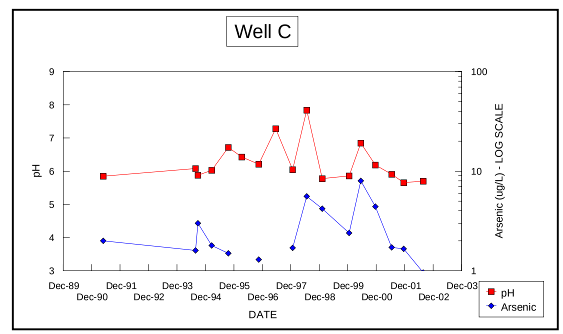

Well A
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

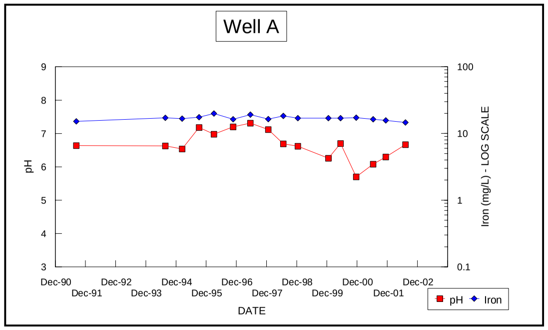

Well B
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

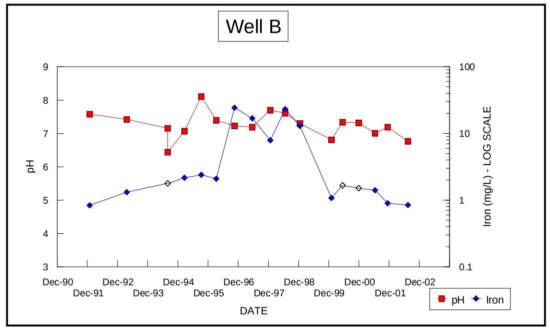

Well C
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

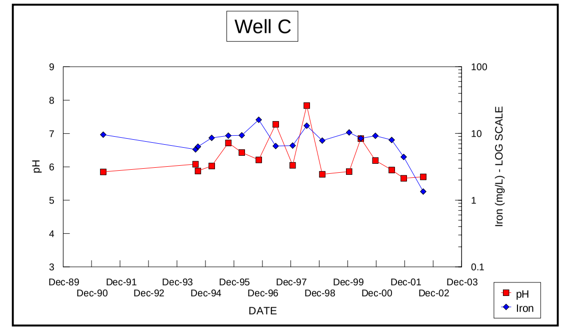

Well A
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

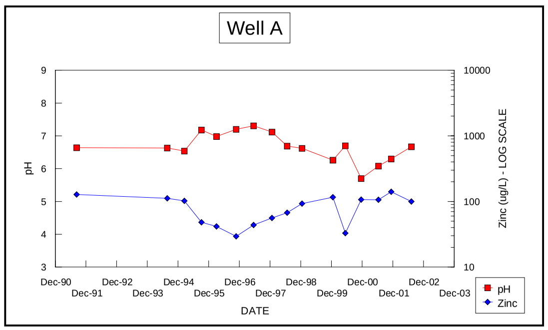

Well B
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

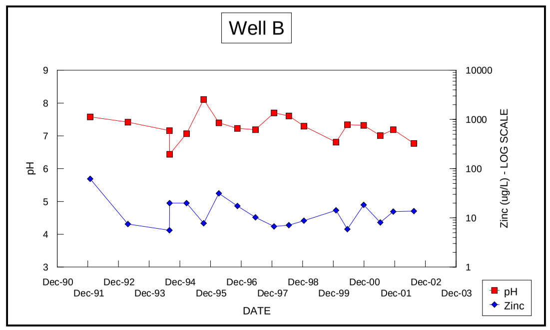

Well C
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

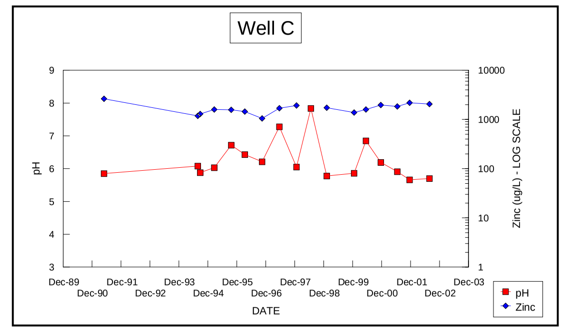

Well A
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

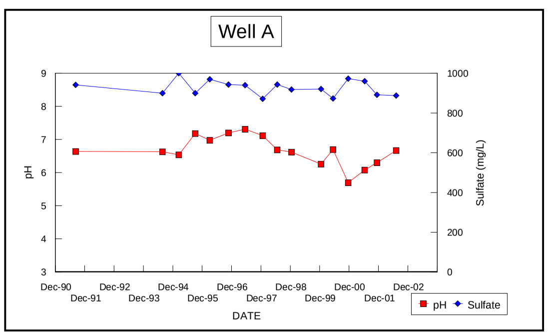

Well B
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

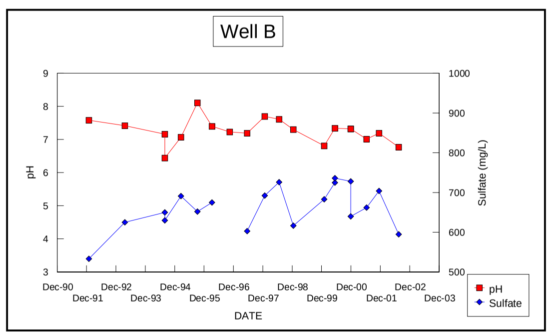

Well C
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

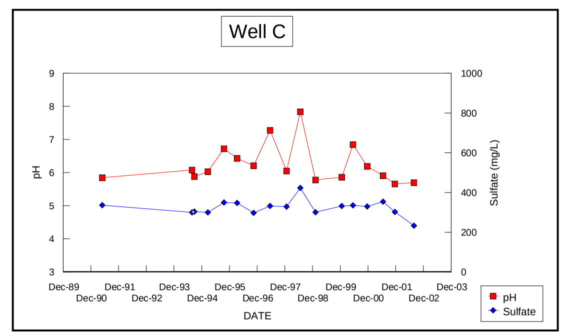

Well A
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

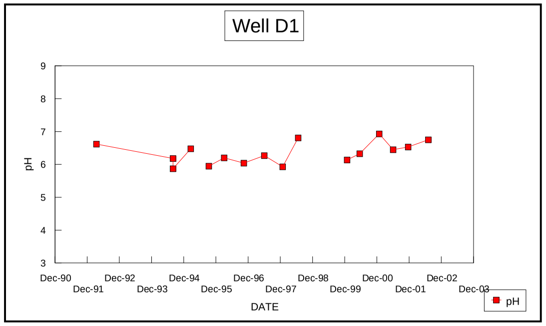

Well B
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

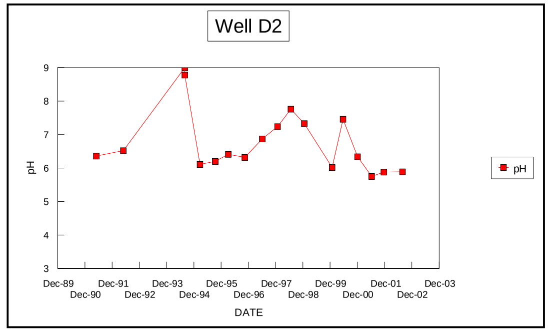

Well C
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

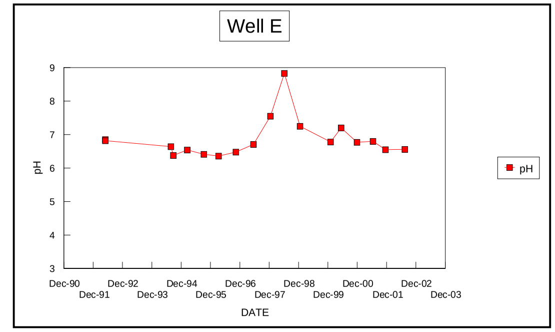

Well A
pH
Sulfate (mg/L)
DATE
pH
Sulfate

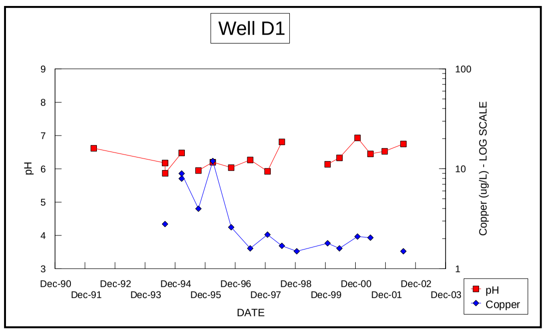

Well B
pH
Sulfate (mg/L)
DATE
pH
Sulfate

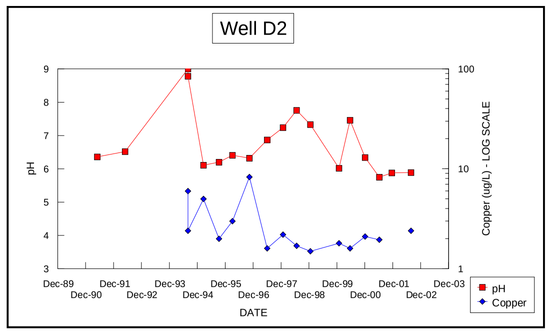

Well C
pH
Sulfate (mg/L)
DATE
pH
Sulfate

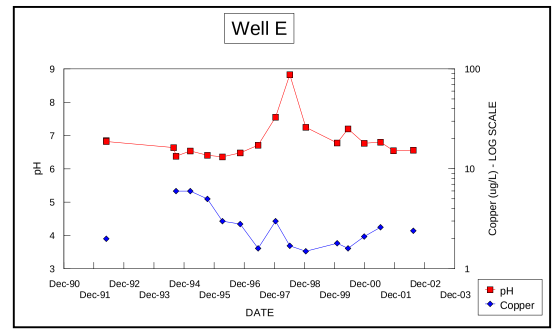

Well D1
pH
DATE
pH

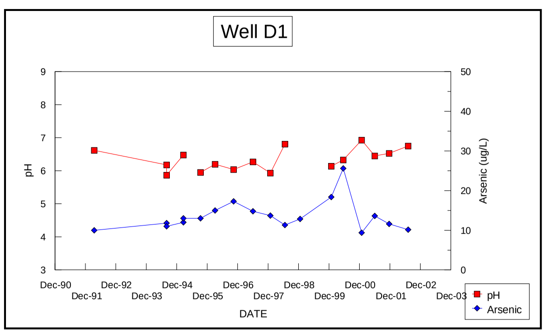

Well D2
pH
DATE
pH

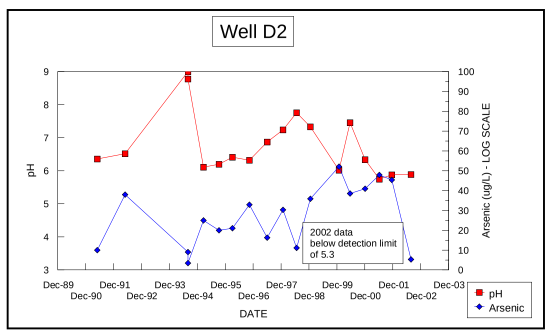

Well E
pH
DATE
pH

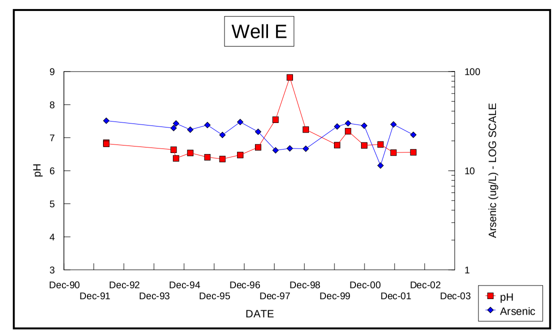

Well D1
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

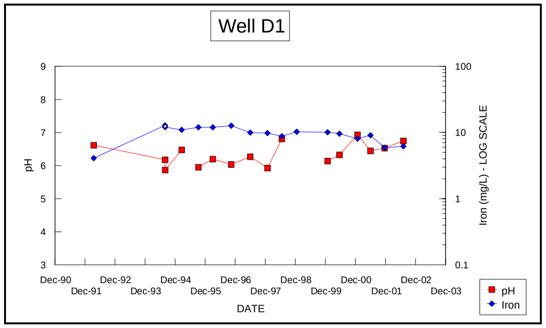

Well D2
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

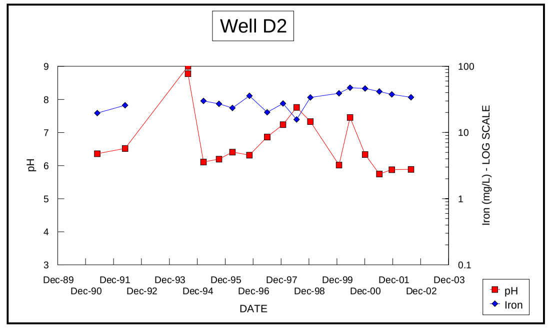

Well E
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

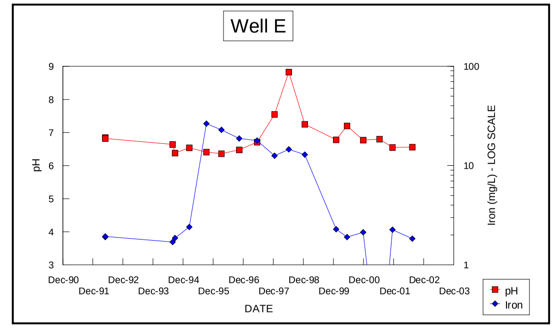

Well D1
pH
Arsenic (ug/L)
DATE
pH
Arsenic

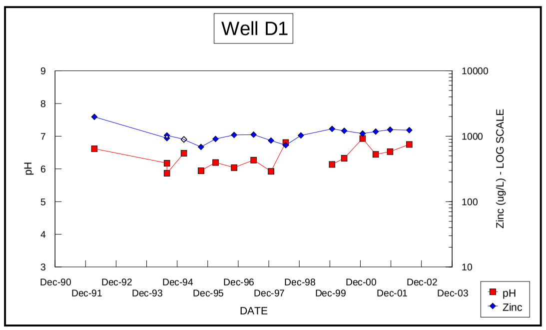

Well D2
pH
Arsenic (ug/L) - LOG SCALE
2002 data below detection limit of 5.3
DATE
pH
Arsenic

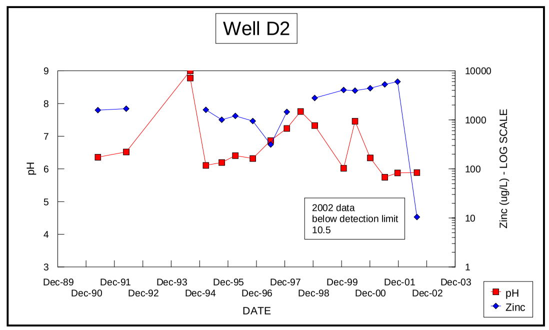

Well E
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

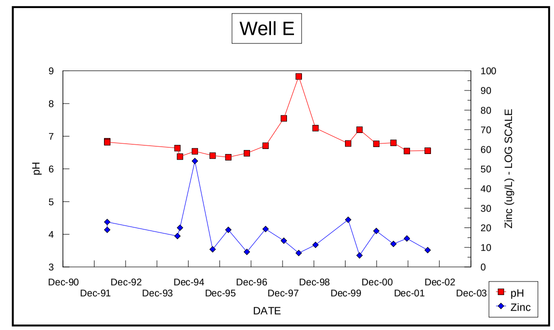

Well D1
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

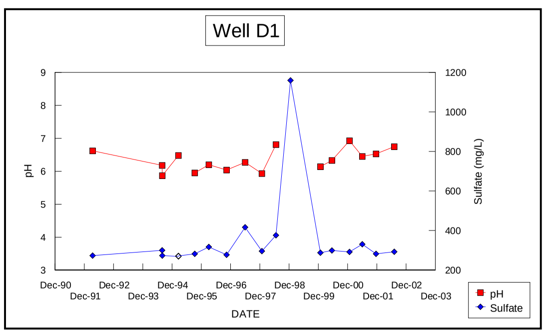

Well D2
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

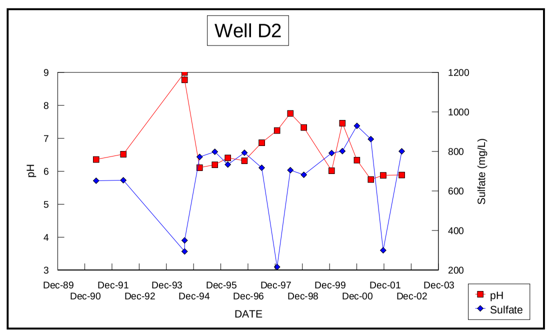

Well E
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

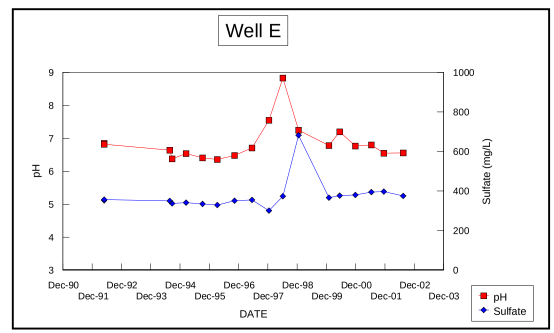

Well D1
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

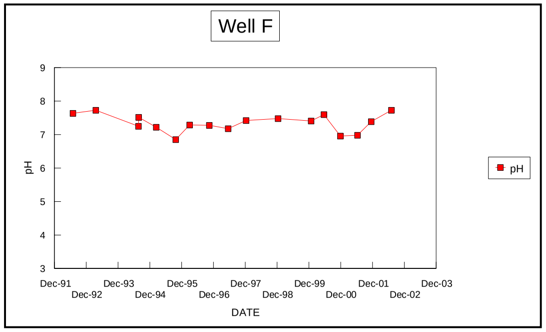

Well D2
pH
Zinc (ug/L) - LOG SCALE
2002 data
below detection limit
10.5
DATE
pH
Zinc

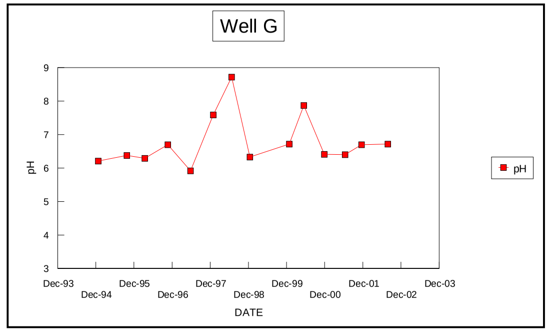

Well E
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

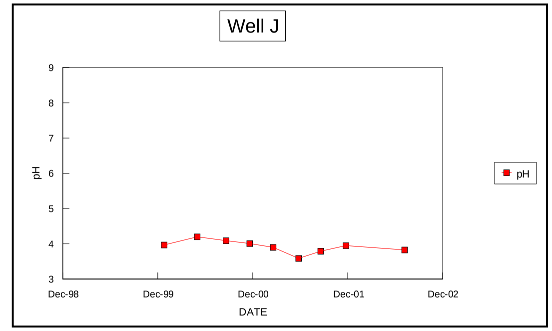

Well D1
pH
Sulfate (mg/L)
DATE
pH
Sulfate

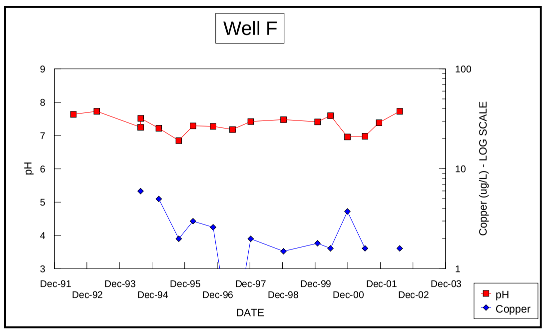

Well D2
pH
Sulfate (mg/L)
DATE
pH
Sulfate

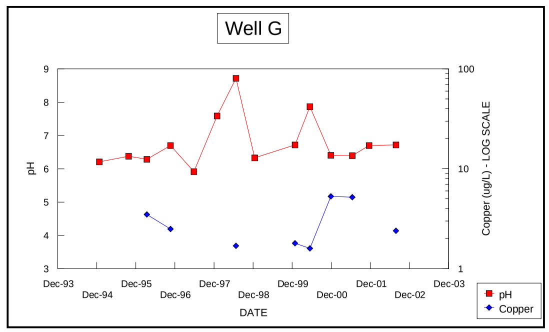

Well E
pH
Sulfate (mg/L)
DATE
pH
Sulfate

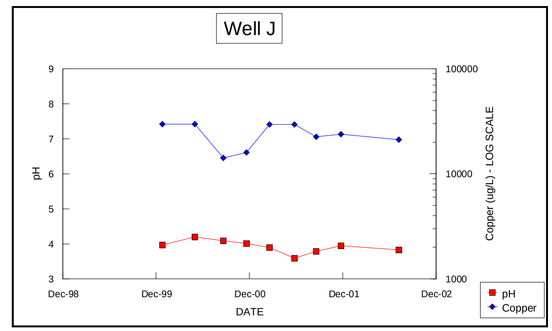

Well F
pH
DATE
pH

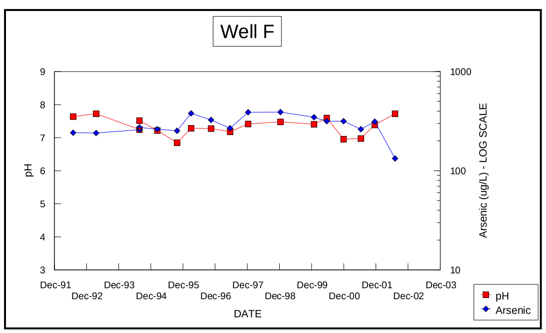

Well G
pH
DATE
pH

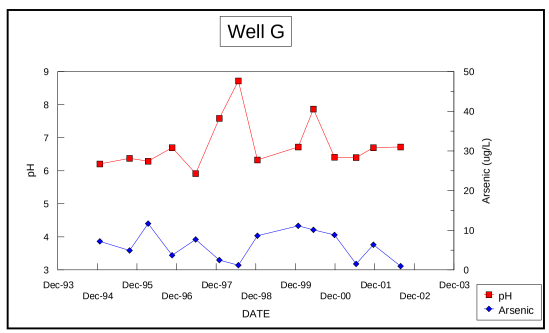

Well J
pH
DATE
pH

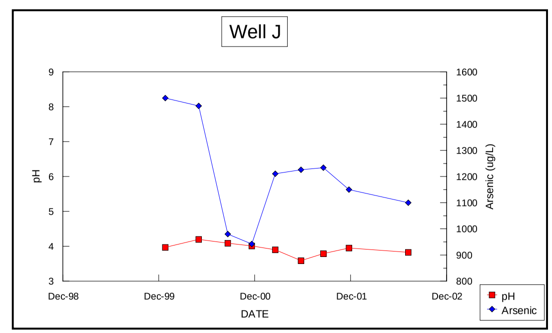

Well F
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

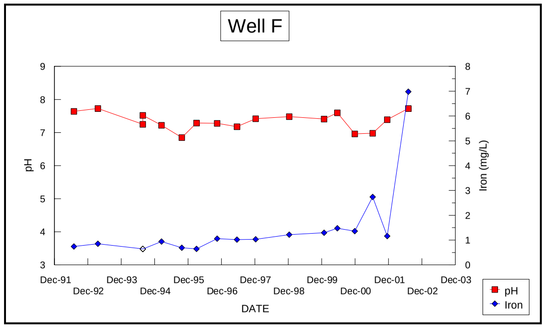

Well G
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

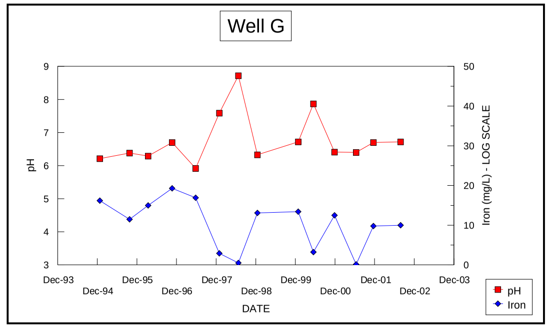

Well J
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

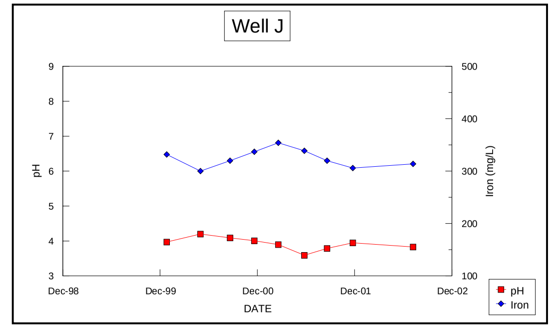

Well F
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

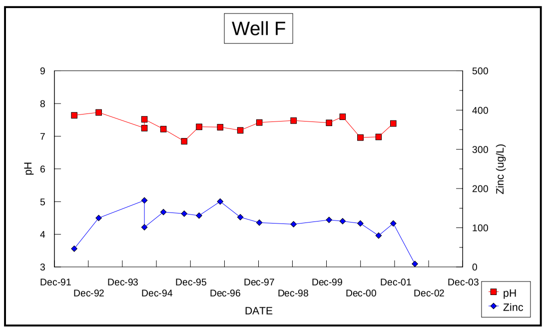

Well G
pH
Arsenic (ug/L)
DATE
pH
Arsenic

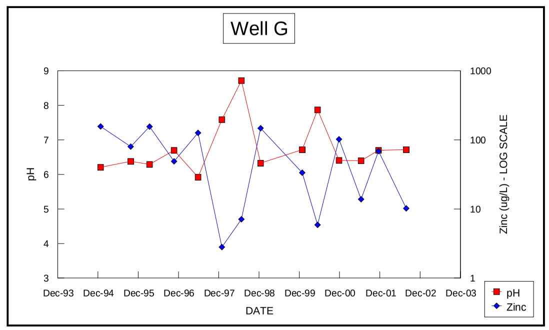

Well J
pH
Arsenic (ug/L)
DATE
pH
Arsenic

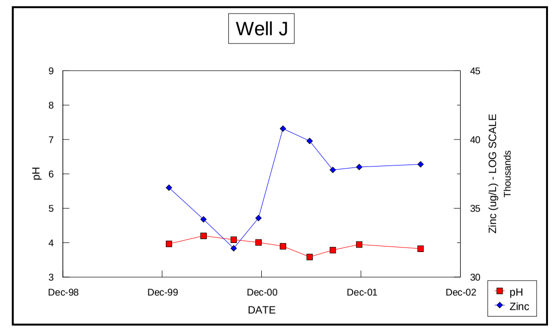

Well F
pH
Iron (mg/L)
DATE
pH
Iron

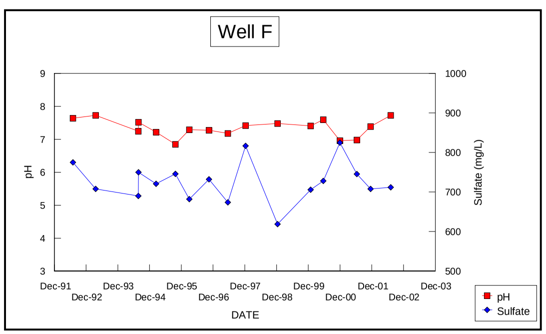

Well G
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

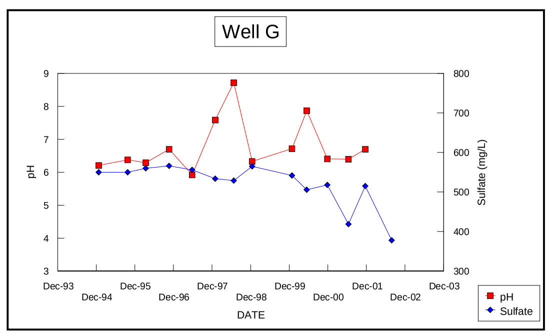

Well J
pH
Iron (mg/L)
DATE
pH
Iron

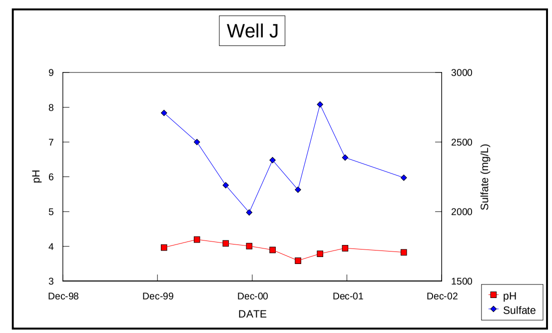

Well F
pH
Zinc (ug/L)
DATE
pH
Zinc


Well G
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc


Well J
pH
Zinc (ug/L) - LOG SCALE
Thousands
DATE
pH
Zinc


Well F
pH
Sulfate (mg/L)
DATE
pH
Sulfate


Well G
pH
Sulfate (mg/L)
DATE
pH
Sulfate


Well J
pH
Sulfate (mg/L)
DATE
pH
Sulfate